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The productive traits, fatty acid profile and nutritional indices of three lupin (*Lupinus* spp.) species cultivated in a Mediterranean environment for the livestock

Biagina Chiofalo[a,*], Vittorio Lo Presti[a], Vincenzo Chiofalo[a], Fabio Gresta[b]

[a] *Dipartimento di Morfologia, Biochimica, Fisiologia e Produzioni Animali, Università di Messina, Polo Universitario Annunziata, 98168 Messina, Italy*
[b] *Dipartimento di Biotecnologie per il Monitoraggio Agro-alimentare ed Ambientale, Università di Reggio Calabria, Loc. Feo di Vito, 89124 Reggio Calabria, Italy*

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ABSTRACT

The aim of this study was to investigate the productive traits and fatty acid profiles of eight sweet varieties of *Lupinus albus*, *Lupinus angustifolius* and *Lupinus luteus* cultivated in a Mediterranean environment (Sicily, southern Italy). This is being done to identify the most suitable species, from an agronomical and nutritional point of view, for supporting animal husbandry in this area. Seed yield, oil quantity and oil quality were considerably different depending on the genotype. *L. albus* showed the highest yield (2.0–2.4 t/ha), 100 seed weight (27.0 g, on average), oil content (70.4–75.5 g/kg), and $n-3/n-6$ polyunsaturated fatty acid ratio (0.39–0.51), *L. angustifolius* showed the highest content of saturated fatty acids (21.03–26.66 g/100 g) and *L. luteus* showed the highest levels of $n-6$ polyunsaturated fatty acids (47.56–50.85 g/100 g), unsaturated/saturated (4.93–5.62) and polyunsaturated/saturated (3.33–3.99) fatty acid ratios and the best atherogenic (0.06) and thrombogenic (0.09–0.11) indices. The data obtained suggests *L. albus* as the most interesting lupin species for aiding the crop-livestock food chain and *L. luteus* as a promising crop due to its high nutritive traits for the Mediterranean environment.

1. Introduction

World agriculture is facing two challenges: ensuring adequate food production for an ever-increasing human population while protecting natural resources from pollution. The use of nitrogen that is biologically fixed by legumes to support the production of non-legume crops, can improve soil fertility while at the same time having a less detrimental effect on the environment when compared with the use of inorganic fertilizers (Bhardwaj et al., 2004). This is particularly the case in the Mediterranean environment where the climatic conditions strongly limit the use of spring-summer cycle crops. In this context, lupin potentially represents a solution for both challenges since it has a winter cycle, is well adapted to Mediterranean climate (Annicchiarico and Carroni, 2009); it also manifests high grain productivity for food and feed destination, has limited requirements compared to many other crops (Bolland and Brennan, 2008), has a high content of proteins deriving from nitrogen fixed from atmosphere (Sujak et al., 2006) and is an excellent rotation crop able to enrich soil with nitrogen

Abbreviations: AI, atherogenic index; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; FA, fatty acid; FAME, fatty acid methyl ester; GC–FID, gas chromatography–flame ionization detector; HI, harvest index; LAI, leaf area index; LC-PUFA, long chain polyunsaturated fatty acids; MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid; TI, thrombogenic index; UFA, unsaturated fatty acid.

* Corresponding author. Tel.: +39 090 3503592; fax: +39 090 3503973.
E-mail address: biagina.chiofalo@unime.it (B. Chiofalo).

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(McNeill and Fillery, 2008). While great attention has been paid to the quantity and quality of lupin protein (Suchy et al., 2008; Duranti et al., 2008), much less research has been undertaken on the quality of lupin oil.

Unlike crude protein, the level of which varies widely (30–50% depending on lupin species and variety), the oil content in lupin, which ranges between 5% and 10%, is rather low (Suchy et al., 2008). Nevertheless, from a nutritional point of view, oil quality is more important than quantity (Suchy et al., 2008). Lupin oil has a high concentration of tocopherols and sterols when compared to other vegetable oils (Dijkink et al., 2008), as well as an interesting unsaturated fatty acid (FA) profile, mainly consisting of oleic and linoleic acids and ratios between fatty acids which confer upon it specific functionalities. Unsaturated fatty acids (UFAs) are essential nutrients and the $n-3/n-6$ polyunsaturated fatty acids (PUFA) ratio is considered very important with respect to human and animal nutrition. Several authors (Rubio et al., 1998; Viveros et al., 2007) reported finding a lower concentration of plasma cholesterol and triglycerides when lupins were included in the diet of chickens. Moreover, there have been some investigations on the use of lupin seeds as a novel FA source to increase levels of beneficial UFA in meat and milk. Singh et al. (1995) observed an increase of long-chain fatty acids in the milk of lactating cows. Nevertheless, Vicenti et al. (2009) noted similar productive performances when comparing lupin to soybean in the feeding of young bulls.

Lupin is also a useful ingredient in the aquaculture feed industry because of their nutritional characteristics, their high digestibility and some of their unique functional and technical properties that contribute to modern extruded fish feed (Glencross, 2008).

Moreover, lupin has also been studied as a human foodstuff (Reinhard et al., 2006) due to its potential use in functional and healthy food products (Duranti et al., 2008; El-Adawy et al., 2001). The health authorities of many countries promote the intake of foods containing high amounts of $n-3/n-6$ PUFA (Simopoulos, 2003; West Suitor and Meyers, 2006). In fact, $n-3$ PUFAs play a very important physiological role, especially during fetal and infant growth, in the formation of the central nervous system and retinas (Bourre, 2003; Bowen and Clandinin, 2005). They are also important for the prevention of cardiovascular diseases (Galli and Marangoni, 2006; Hu et al., 1999; Simon et al., 1995). Ulbricht and Southgate (1991), in an attempt to evaluate the different effects of the various fatty acids, have proposed two indices, atherogenic index (AI) and thrombogenic index (TI), strictly related to the fatty acid profile, which might better characterize the atherogenic and thrombogenic potential of a vegetable or animal food than a simple approach based on total saturated fatty acids or on the polyunsaturated/saturated fatty acids ratio (PUFA/SFA) (Burr, 1989; Fehily et al., 1994).

On the whole, the increasing selection of sweet varieties that contain very low levels of quinolizidine alkaloids and favorable protein and fiber content (Gresta et al., 2010) as well as the high level of alpha-linolenic acid and the favorable $n-3/n-6$ PUFA ratio has recently opened up the possibility of using white lupin seed in human or livestock nutrition, especially in food chains aimed at supporting animal health and the quality and safety of the organic productions.

The aim of this study was to investigate the agronomic traits, fatty acid profile and nutritional indices of eight varieties of three lupin species (*Lupinus albus* L., *Lupinus angustifolius* L. and *Lupinus luteus* L.) cultivated in a Mediterranean environment, in order to explore the suitability of the different species in regards to animal feed.

2. Materials and methods

2.1. Materials

The trial was carried out in 2007/08 on sandy volcanic soil in Eastern Sicily, Italy (Acireale, CT, 16 m a.s.l.), pH 8.5 and total limestone 30 g/kg. Eight sweet, recently released cultivars of *L. albus* (Luxor and Rosetta), *L. angustifolius* (Wonga, Jindalee and Sonet) and *L. luteus* (Dukat, Mister e Taper) were sown in plots of 6 m^2 (3 m × 2 m) three times replicated in a randomized block design. Sowing was executed on December 27 with 80 plant/m^2 on a ploughed and fertilized soil with 120 kg/ha of P_2O_5. The seeds harvest date for all varieties was May 28. Total yield, 100 seed weight, leaf area index (LAI) and harvest index (HI) were calculated. The weather condition during the crop growth was rather dry, with an average minimum temperature of 12.4 °C, a maximum of 19.5 °C and rainfall of 150 mm. In previous research the tested varieties had been alkaloid free (Gresta et al., 2010) and thus suitable for animal feeding.

2.2. Sample preparation and extraction of crude oil

The extraction of the crude oil from the lupin seeds was carried out according to the Boschin et al. (2008) method. Lupin seeds were ground in a household mill, 12 g of flour were extracted with hexane (300 ml) for 6 h in an automated Soxhlet apparatus (Foss Electric, Hillerød, Denmark) using cellulose extraction thimbles (123 mm × 45 mm o.d., 43 mm i.d., Whatman International, Brentford, UK). The solvent was then evaporated under reduced pressure. The oil content was gravimetrically determined and expressed as g/kg of lupin flour. The crude oil analysis of each sample was replicated three times.

2.3. Extraction and identification of fatty acid methyl esters (FAMEs)

The fatty acids methyl esters (FAMEs) of the lupin seeds were prepared by direct transesterification (Christie, 1993). The oil extracted from each sample of lupin was suspended in a mixture of sulphuric acid/methanol (1:9, ml/ml) and heated for