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White Lupin as a New Crop for Plant Proteins

Henrina Torbo[1] & Harbans L. Bhardwaj[1]

[1] Agricultural Research Station, Virginia State University, Petersburg, VA, USA

Correspondence: Harbans L. Bhardwaj, Agricultural Research Station, Virginia State University, Petersburg, Virginia 23806, USA. Tel: 1-804-524-6723. Fax: 1-804-524-5950. E-mail: hbhardwaj@vsu.edu

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Abstract

The world is demanding more protein for human consumption-increasing amounts of plant proteins are being used to meet this increasing demand. It has been estimated that global plant-based alternative protein market could swell to $162 billion in the next decade from $29.4 billion in 2020 and every tenth portion of meat, eggs, and dairy eaten around the globe by 2035 could be derived from plant proteins. White lupin (*Lupinus albus* L.), a legume, has been researched in Virginia for several years which has resulted in development of several winter-hardy and high yielding lines. However, concentrations of protein and relative concentrations of various amino acids in seeds of these lines are not known. Therefore, objective of this study was to characterize protein in winter-hardy lupin lines. Seeds of five winter-hardy white lupin lines grown during 2020-2021 contained about 51% protein as compared to literature values of about 35 and 24% protein in soybean and winter pea seeds, respectively. Concentrations of nine essential amino acids (isoleucine, leucine, lysine, methionine, threonine, tryptophan, valine, phenylalanine, and histidine) in lupin seed varied from 1.25 to 1.41, 1.98 to 2.51, 1.12 to 1.60, 0.21 to 0.27, 1.03 to 1.28, 0.25 to 0.30, 1.22 to 1.40, 1.14 to 1.28, and 0.69 to 0.79, respectively. These concentrations compared quite well with those in soybean and winter pea seed. These results indicate that white lupin has considerable potential to meet alternative plant protein needs of manufactures and consumers.

Keywords: *Lupinus albus*, plant proteins, amino acids, food quality

1. Introduction

1.1 Problem

Recent interest in plant proteins provided an impetus for the current study. World is demanding more protein—protein is a key ingredient in our diets—total protein demand is increasing, driven by a growing human population. People are consuming more plant proteins—consumers are demanding greater choice of healthier and more sustainable food protein options. Plant based foods are no longer niche and are starting to form a more central part in the innovation pipelines of food and drink brands.

1.2 Justification

CSIRO (2022) has estimated that by 2050, 60 percent more food will be needed to feed an expected 9.7 billion people in the world. Global protein demand, measured in terms of total macronutrients consumed, is expected to increase 20% between 2018 and 2025 to 271 million tonnes driven by a growing global population and a rising middle class. This demand will necessitate increased production of livestock alongside complementary increases in plant-based protein sources. Focusing on an outlook to 2030 with both ambitious and conservative scenarios, CSIRO predicted that the current plant-protein market of $140 million could balloon to between $3 billion and $9B in less than ten years. Although this is a major jump, the figures are small compared to the conservative estimate for the overall Australian protein market, which is set to hit $76B by 2030. Most plant proteins are currently derived from soybean and yellow pea, two plants with limited scope in Australian agriculture. Australia, therefore, is focusing on Australian-grown pulses such chickpeas, faba (or fava) beans, mung beans, lupin, field peas and lentils.

A report from Tufts University (Boston, Massachusetts) Health & Nutrition Letter 2020 report indicates that consumer demand for plant-based protein is growing. Fourteen percent of U.S. consumers surveyed for the report indicated regularly consuming plant-based protein sources such as tofu and veggie burgers, even though the vast majority did not consider themselves vegan or vegetarian (Anonymous, 2020a).

A publication of Lux Research (Lux Research, 2020) indicated that since 2015, the plant protein space has experienced an unprecedented level of commercial activity, much of it just since Beyond Meat went public in May 2019. The nature of the activity alongside ongoing trade affairs is signaling the need for three attributes, which hinge on crop production factors: 1) protein source diversity, 2) scalability, and 3) regional resiliency. Conventional meat, fish, and poultry are insufficient to sustainably satisfy protein demand. The global population is swelling toward 10 billion, with more demand for animal protein as more countries grow richer. This has given rise to next-generation methods for protein production, including plant proteins, insect proteins, algae, and cellular agriculture. Plant proteins are experiencing increasing commercial maturity as product launches, market expansions, and manufacturing facility constructions accelerate.

McDonalds recently announced plans to debut "McPlant", a pea-protein based "burger" (Anonymous, 2020b).

1.3 Background

The preceding indicates a robust future for development of existing and new crops as sources of protein. As of now, no winter crop that can serve as an optimal source of plant proteins is available for production in Virginia and the mid-Atlantic region. However, white lupin (*Lupinus albus* L.), a legume plant, has considerable potential to provide proteins to meet plant protein demands.

White lupin is a member of the bean family that also contains beans, peanut, and soybean. White lupin has a long history in southern United States. At one time, over two million acres of blue, yellow, and white lupin were grown in the southern United States as green manure for cotton. Lupin can potentially fix 150 to 200 kg nitrogen/ha for use by a succeeding crop. Consecutive hard freezes, cheap fertilizers, and government programs favoring other crops contributed to lupin's demise so that by the 1960s, it had essentially disappeared. White lupin started to get increasing research focus in 1990s as a source of food.

White lupin is receiving increasing attention due to its' high potential to provide a rotation yield response to proceeding summer grain crops, contribute to reducing or eliminating N fertilizer input, and producing quantities of high protein grain (Bhardwaj & Hamama, 2012; Bhardwaj et al., 2004). White lupin has been researched in Virginia for several years. The New Crops Program of Virginia State University (Harbans Bhardwaj as Principal Investigator) started lupin evaluations in 1998 with 79 lines/varieties of white lupin; over the years, the total genetic material tested has included about 400 white lupin lines/varieties. Several field experiments were conducted in the last 30+ years at Randolph Farm of Virginia State University (Petersburg, Virginia). These studies supported development of winter hardy, high-yielding varieties that are suitable for production in Virginia. However, concentrations of protein and relative concentrations of various amino acids in these lines were not known. Therefore, objective of this study was to characterize protein in winter-hardy lupin lines.

2. Methods

2.1 Plant Material

Seeds from five white lupin lines (VSU-1, VSU-1X, VSU-5, VSU-10, and VSU-101) were used in this study. These five lines were selected from ten white lupin breeding lines that were grown in the field at Randolph Farm of Virginia State University during 2020-21 crop season. The main criterions for selection were winter-hardiness and seed productivity.

2.2 Experimental Details

The plots consisting of four 3-meter long rows spaced 37.5 cm apart, were planted on September 29, 2020 using a Randomized Complete Block Design with three replications. Each row was planted with about 100 seeds Experimental area received a preplant incorporated treatment of Trifluralin herbicide at the rate of 1 $L \cdot ha^{-1}$. The plots were manually weeded once. The plots were harvested on June 22-24, 2021 with a research combine (Almaco, 99 M Ave, Nevada, IA 50201). Upon harvest, seeds were weighed to record yield and other data.

2.3 Analytical Details

Seeds from five white lupin lines with winter-hardiness and highest seed yields (VSU-1, VSU-1X, VSU-5, VSU-10, and VSU-101) were used to determine concentrations of protein and various amino acids. These analyses were conducted by a commercial laboratory (Eurofins, Des Moines, Iowa 50321) using standard AOAC procedures (AOAC, 2016).

2.4 Statistical Analysis

All data were analyzed using version 9.1 of SAS (SAS, 2014) using ANOVA with 5 percent level of significance. Concentrations of fat, protein, and amino acids in white lupin seeds in this study were compared to those in the literature for soybean and winter pea.

3. Results

3.1 Amino Acids in White Lupin Seeds

Five winter-hardy white lupin lines differed for their amino acid concentrations in the seeds (Table 1). However, the differences were not very profound, perhaps due to a small number of lines being evaluated. The results indicated that variation among five lines was more pronounced for concentrations of Glutamic acid, Arginine, and Lysine (Range values of 1.82, 0.49, and 0.48, respectively) and least pronounced for concentrations of Histiine, Proline, and Tryptophane (Range values of 0.03, 0.04, and .04, respectively). White lupin seeds in this study contained Glutamic acid, Aspartic acid, Arginine, Leucine, Serine, Isoleucine, Valine, Proline, Lysine, Glycine, Tyrosine, Phenylalanine, Threonine, Alanine, Histidine, Cystine, Tryptophane, and Methionine (In descending magnitude of concentration).

Table 1. Concentrations of amino acids (%) in seeds of five white lupin lines grown in Virginia during 2020-21

	VSU-1	VSU-1X	VSU-5	VSU-10	VSU-101	Mean±SD
Alanine	1.14	1.18	1.04	1.08	1.09	1.106±0.055
Arginine	2.88	3.02	3.37	3.37	2.98	3.054±0.186
Aspartic acid	3.39	3.33	3.56	3.56	3.28	3.374±0.111
Cystine	0.48	0.42	0.57	0.48	0.50	0.490±0.054
Glutamatic acid	6.37	6.22	8.04	8.04	7.01	6.862±0.725
Glycine	1.28	1.32	1.30	1.30	1.28	1.298±0.018
Histidine	0.73	0.73	0.74	0.74	0.75	0.742±0.013
Isoleucine	1.38	1.38	1.41	1.41	1.34	1.368±0.033
Leucine	2.51	2.39	2.50	2.50	2.37	2.422±0.078
Lysine	1.12	1.52	1.59	1.60	1.54	1.474±0.201
Methionine	0.26	0.27	0.21	0.25	0.30	0.244±0.024
Phenylalanine	1.28	1.27	1.22	1.21	1.20	1.236±0.036
Proline	1.28	1.32	1.31	1.30	1.29	1.300±0.016
Serine	1.65	1.62	1.77	1.63	1.67	1.668±0.060
Threonine	1.26	1.28	1.14	1.21	1.18	1.214±0.057
Tryptophane	0.29	0.29	0.25	0.29	0.27	0.278±0.018
Tyrosine	1.29	1.30	1.32	1.27	1.24	1.284±0.030
Valine	1.39	1.40	1.33	1.37	1.34	1.366±0.030

3.2 Fat, Protein and Amino Acid Concentrations in White Lupin, Soybean, and Winter Pea

Concentrations of protein and various amino acids are presented in Table 2. Amino acid concentrations in seeds of white lupin were essentially better than or equal to those in seeds of soybean and white pea – two crops that are current mainstays of alternative protein market. Results indicated that white lupin (mean over five selected lines) had approximately 40% more protein than soybean and more than double the protein in winter pea. Total concentration of amino acids in white lupin (means over five selected lines) were greater than those in soybean and winter pea: 34.04% in white lupin, 16.803% in soybean, and 1.77% in winter pea (Feedipedia, 2017; FoodData Central, 2019).

Table 2. Concentrations of fat, protein and amino acids (%) in seeds of white lupin grown in Virginia during 2020-21

Trait	White lupin[x]	Soybean[a]	Winter pea[a]
Fat	8.8	19.9, 21.4	0.68, 1.2
Protein	50.8	36.5, 39.6	23.9, 23.9
Tryptophane	0.94	0.59, b	b, b
Alanine	3.68	1.92, 4.3	0.24, 4.5
Arginine	10.1	3.15, 7.2	0.48, 8.4
Aspartic acid	10.9	5.11, 11.1	0.66, 11.6
Glutamic acid	22.2	7.87, 17.8	1.02, 17.0
Glycine	4.33	1.88,4.2	0.21, 4.4
Histidine	2.55	1.10, 2.6	0.17, 2.5
Isoleucine	4.44	1.97, 4.5	0.17, 4.2
Leucine	7.77	3.31, 7.5	0.36, 7.1
Phenylalanine	4.10	2.12, 5.0	0.25, 4.7
Proline	4.26	2.38, 5.0	0.28, 4.2
Serine	5.37	2.36, 5.0	0.30, 4.7
Tyrosne	3.58	1.54, 3.6	0.13, 3.1
Valine	4.49	2.03, 4.7	0.22, 4.8
Threonine	3.94	1.77, 3.9	0.19, 3.8
Lysine	5.02	2.71, 6.2	0.38,7.2
Methionine	0.79	0.55, 1.4	0.07, 1.0
Cystine	1.48	0.65, 1.5	0.15, 1.4

Note. x: values are averages over five lupin lines grown in Virginia during 2020-21.

a: Values are averages—First value from Food Central, USDA-ARS, and second number from Feedipedia.

b: not available.

W observed that white lupin seeds could be a better food for human beings. Plants are the major food source for humans and other animals, providing carbohydrates, protein, lipids and vitamins (Ismande, 2003). Protein accounts for approximately 10 to 15% of the dry weight of cereal grains, 20 to 25% of the dry weight of many legume seeds, and 40% of the dry weight of a typical soybean seed. Even though cereal grains and legume seeds are excellent sources of protein, many are deficient in at least some of the ten essential amino acids. Maize, for example, is deficient in both lysine and tryptophan, whereas legume seeds are frequently deficient in the sulfur amino acids, methionine and cysteine. Concentrations of methionine and cysteine in white lupin seeds in the current study, in general, were greater in white lupin seeds and winter pea. This observation along with higher protein concentration in white lupin seed (50.8%) as compared to soybean (approximately 40%) and winter pea (approximately 24%) indicates that white lupin seeds more nutritious for human diets.

Results of this study indicated that white lupin has considerably higher concentration of protein as compared to soybean and winter pea and that white lupin can be a significant source of plant proteins to meet increasing demands.

4. Discussion

The results indicated that winter-hardy white lupin could be easily developed as a source of plant proteins in Virginia and adjoining areas.

It is expected that white lupin as a winter legume crop could replace either some winter wheat or other small grain acres or be planted in fallow fields following field corn. During 2019, Virginia harvested 105,000 acres of winter wheat with an average seed yield of 62 bushels per acre. The returns from each acre of winter wheat during 2019 were $313.10 based on $5.05 per bushel (NASS, 2022). White lupin average seed yield is expected to be about 40 to 50 bushels per acre. Per bushel price of white lupin is unknown at this point in time but two prospective buyers (one in California and one in Ontario, Canada) are complaining that limited imports of lupin from European Union are prohibitively expensive due to cost of seed and shipping. These companies are not being open about the potential price for each bushel of white lupin sources from Virginia but there are indications that a possible price per bushel of white lupin could be expected to be around $8 to $10 per bushel before freight. This indicates that white lupin produced in Virginia would be economically competitive.

Additionally, white lupin producers are expected to save on costs of nitrogen fertilizer needed for succeeding crops. White lupin, being a legume, would not would not need nitrogen fertilizer for its production.

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Disclaimer

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