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REVIEW ON NUTRITIONAL, ANTI NUTRITIONAL CONTENT AND EFFECT OF PROCESSING ON ANTI NUTRITIONAL CONTENT OF LUPINE IN ETHIOPIA

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ABSTRACT: *White lupine is a traditional crop in Ethiopia. It is grown in the north western part of the country. Lupine has been used as human nutrition especially the protein content is very high (40%) which can solve the malnutrition problem in Ethiopia. The utilization of lupine is limited by small scale of their production, market and the anti nutritional content. The utilization can increase using effective anti nutritional removing methods. Alkaline thermal treatment, Aqueous thermal treatment, Extrusion cooking are efficient methods to remove anti nutrients in lupine. Nowadays in Ethiopia by safe processing using traditional processing methods(roasting followed by socking) by removing of Anti nutritional factor applied in the production of different kinds of Functional foods such as cooked, roasted , ground and mixed with cereal flour in the production of bread, snack, Injera , Shero, Kolo(roasted food), Nefro(cooked food).*

KEY WORD: lupine, nutrition, and processing effect

INTRODUCTION

White lupine is the longest known crop species in the history of the genus *Lupines* it was known among Aegean farmers before 400 years B.C. Until the beginning of the 19th century in Europe in the Mediterranean Sea region it was the most often cultivated lupine species for green manure and for seeds which were used in animal and human nutrition(Prusinski, 2017). The use of white lupine as food is applied in the Mediterranean area from many centuries whereas the application in human nutrition of narrow leaf lupine which is mainly cultivated in Australia is much more recent. Both are rich in protein as well as dietary fiber and poor in digestible carbohydrates(Arnoldi et al., 2013).

Lupine cultivation in the world is targeted for the use of the crop as livestock feed, soil fertilizer,

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and human food. One of the limitations of lupine is its alkaloid content which is responsible for bitter taste and toxicity of lupine products in human food and livestock feed. Based on their content of toxicquinolizidine alkaloids the available cultivated lupines in the world (*Lupinus albus*, *L. angustifolius*, *L. mutabilis*, *L. luteus*) are categorized into two groups; bitter and sweet varieties(Likawent Yeheyis et al. 2011). Researchers reported the major nutritional problem in most developing countries is protein energy malnutrition. This acute problem is due to factors such as high birth rates, insufficiency of agricultural products, lack of utilization of marginal crops and limited supply of high quality proteins. Therefore this review is planned to explain for the readers to review The Nutritional, Anti nutritional, effect of processing on the anti nutritional content of Lupine.

L. angustifolius ***L. albus (white)*** ***L. luteus (yellow)*** ***L. mutabilis***

Figure 1. Lupine species in the world

Production and utilization of lupin

Wild lupines (*Lupinus* spp.) are believed to have originated and be concentrated in two large areas: The old world or Mediterranean region (Eastern hemisphere) and the new world or American (Western hemisphere). Among the four commercially important large seeded sweet annual lupine species, narrow leafed lupine (*Lupinus angustifolius* L.), white lupine (*Lupinus albus* L.), and yellow lupine (*Lupinus luteus* L.) are widely grown species in the world(Figure 1). The common cultivation areas of these species are Europe, Australia, South Africa and North and South America(Figure 2 and 3). In most parts of the world the vast majority of lupine seed produced each year is used for livestock feeding and human nutrition.

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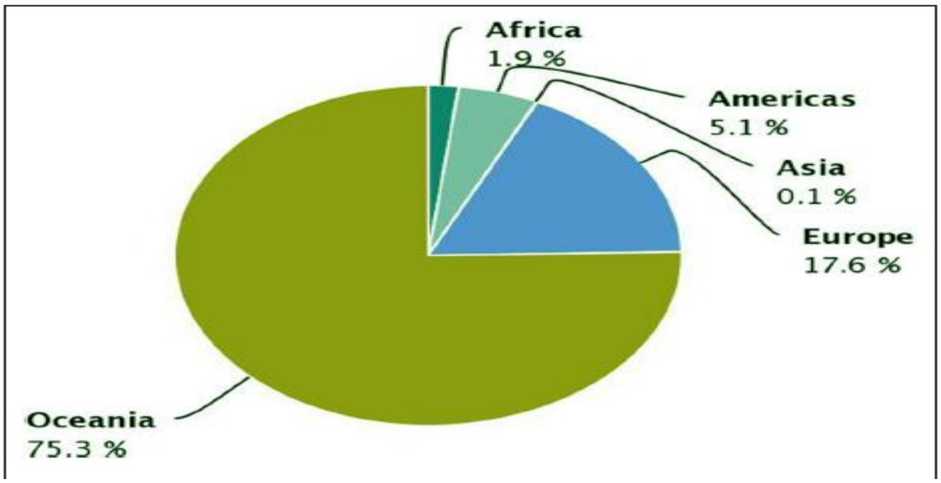

Figure 2. Worldwide distribution of lupine production. Source:(Lucas et al. 2015)

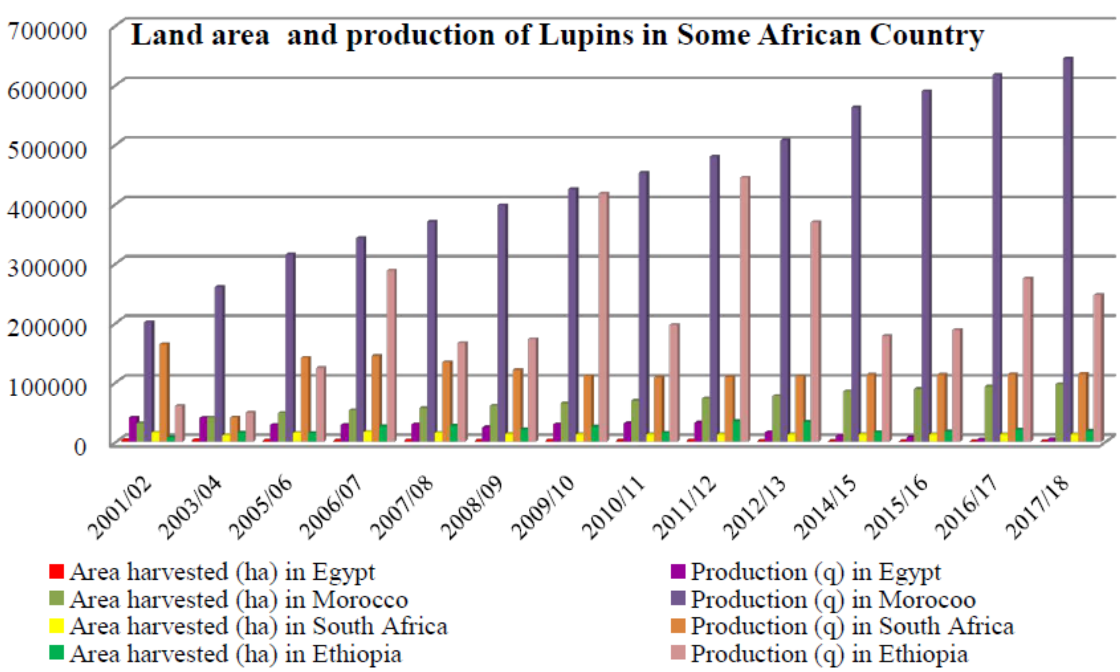

Figure 3. Trends of land coverage (ha) and its production (q) of lupin in Four African countries. Source (A. A. Habtemariam et al., 2019)

White lupine is a traditional crop in Ethiopia. It is grown in the north western part of the country. According to Yeheyis et al. (2011) study report the local white lupine in Ethiopia is a very

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important traditional multipurpose crop and is grown in mixed crop livestock farming systems of the area. The same authors reported that under traditional management systems the average grain yield potential of the crop is 1.2 t/ha. However, the use of the crop as human food and as livestock feed is limited due to its bitter taste attributed to its relatively high alkaloid content (1.43%) (Yeheyis et al. 2012). While The sweet lupine yield (2.67 t/ha)(Alemu Asmare, and Yeheyis ,2019) in Ethiopia.

Habtemariam, Woldetsadik, and Belay., (2019) reported in Ethiopia the overall trends of Lupine production also observed high degree of fluctuations (Figure 4, 5 and 6). Azeze et al. (2016) showed similar results in the country. This indicates that the crop gained less attention by the government, lack of well known improved varieties, and lack of aware farmers might be the cause of its decline.

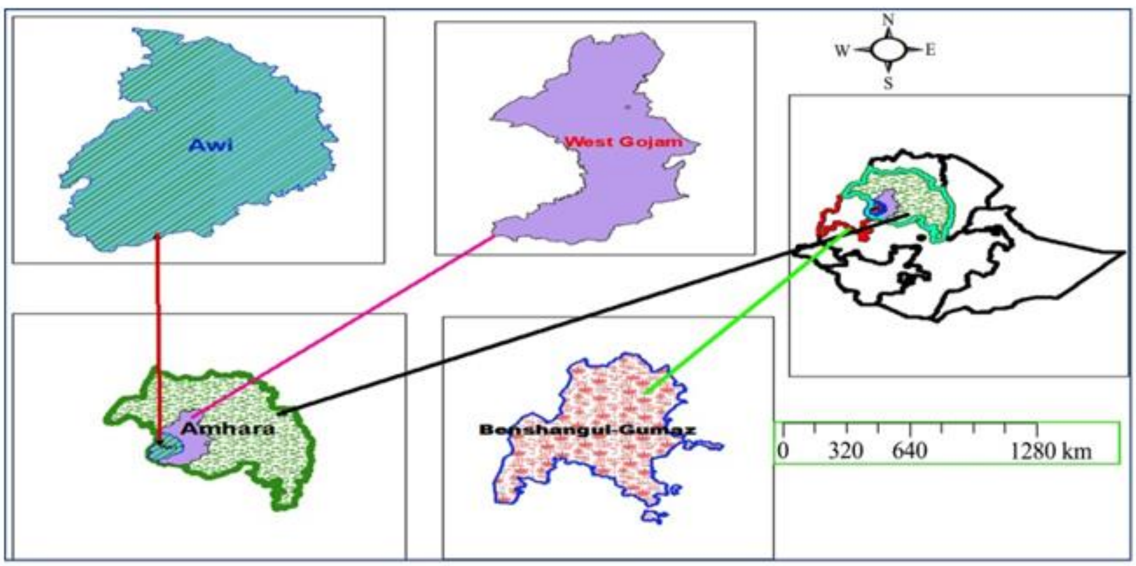

Figure 4. Major growing areas (brown colored) of white lupine in Ethiopia. Source (Habtemariam, Woldetsadik, and Belay.,2019)

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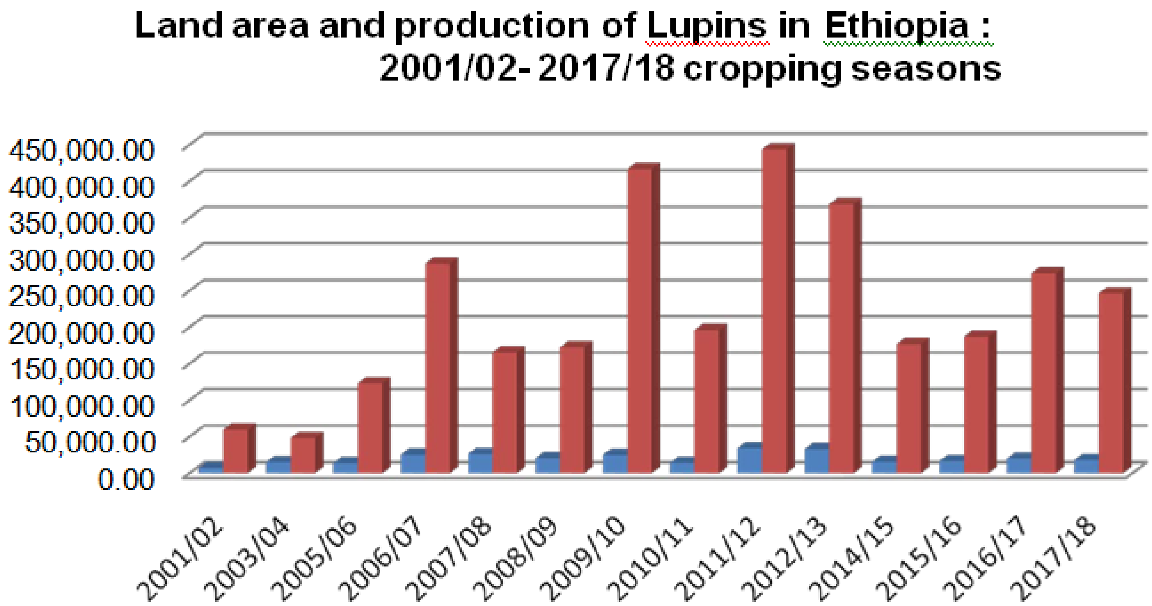

Figure 5. Trends of land coverage and production (q) of Lupine in Ethiopia. Source (Habtemariam, Woldetsadik, and Belay.,2019)

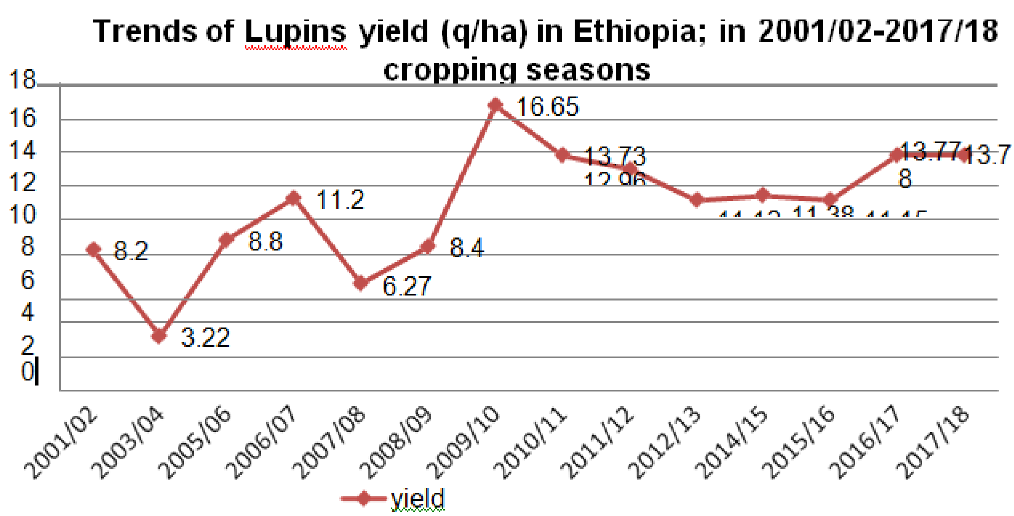

Figure 6. Trends of Lupine yields (q/ha) in Ethiopia. Source (Habtemariam, Woldetsadik, and Belay.,2019).

White lupine seed is commonly used as supplementary food preparation in the form of snack and its flour is also used as traditional sauce as a component of meal with local bread and *Injera*. Equivalent to its food value, consumers have the perception of its hypertension treatment role on

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consumption of white lupine snack and drinking the alcohol prepared from its seed. White lupine seed has been used for hypertension control in traditional medicinal practices in North Western Ethiopia since longer period of time. Habtemariam, Woldetsadik, and Belay., (2019)reported In Ethiopia, the consumption of lupine at the farm household level is limited (35%) due to a social taboo that says, "Lupin is for the poor and it is unsuitable nutrition". Therefore, farmers were not aware about the utilization customs the plant as a household consumption. Lupine seeds are consumed in Ethiopia as snack by roasting followed by soaking in running water to remove the alkaloids which are responsible for the bitter taste for 4-9 days and washing it twice (Likawent Yeheyis et al. 2011). In Ethiopia it is consumed as snack and lupine powder for preparation of stew/sauce ("*shiro*") like other common legumes. White lupine is used to prepare local alcohol *Areki* and local sauce (locally known as *shiro* and *metata* made from lupine flour) respectively (Figure.7,8 and 9). White lupine consumed as snack or drink in local alcohol(*Areki)* form has been also got vast recognition for its medicinal value for hypertension treatment(Habtie et al., 2009).

Lupine snack in beer house | Lupine snack | lupine based alcohol

Figure 7. Lupine utilization in different form. Source (Hibstu Azeze., 2016)

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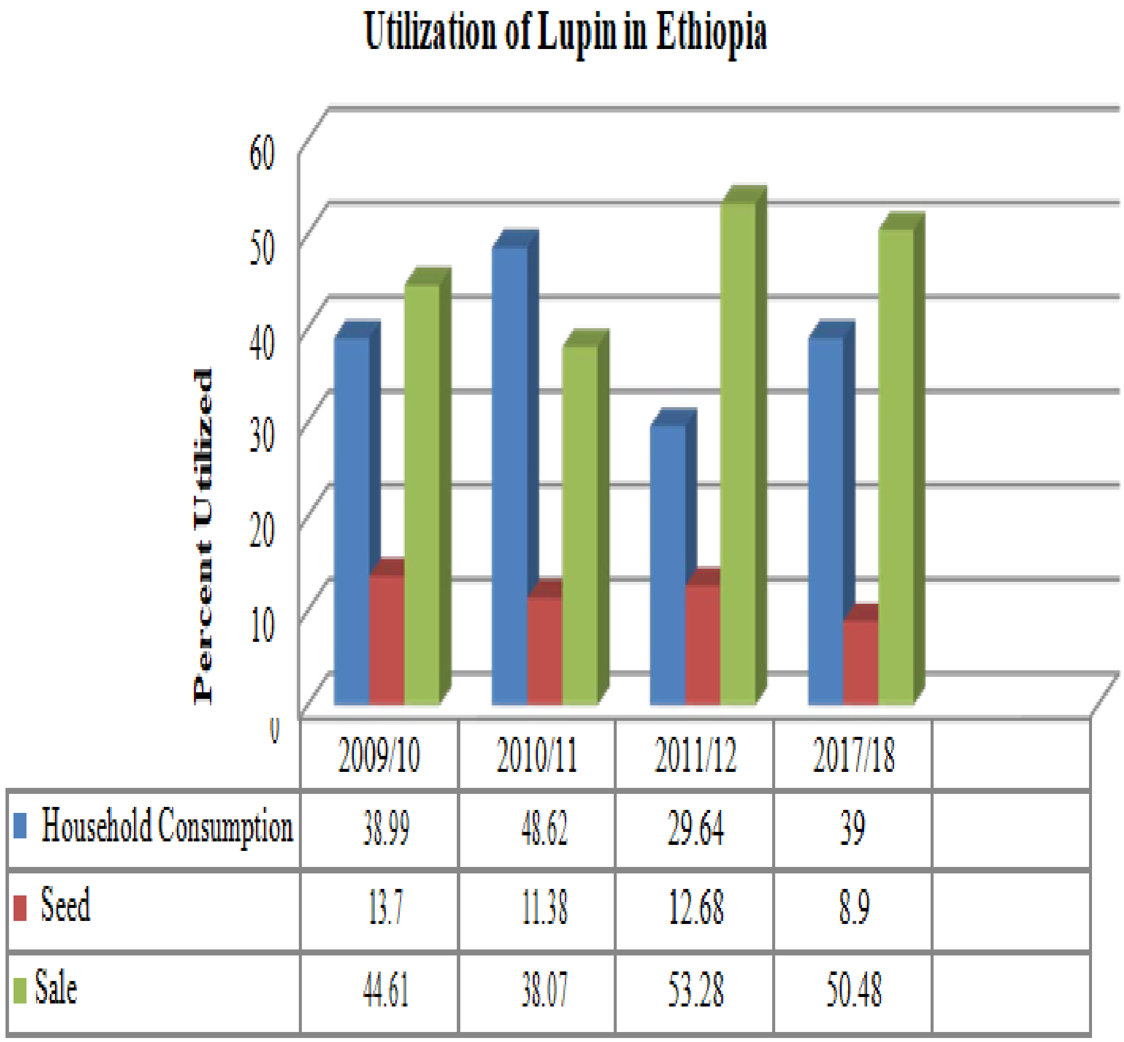

Figure 8 . Utilization trends of Lupine in Ethiopia
Source (Habtemariam, Woldetsadik, and Belay.,2019)

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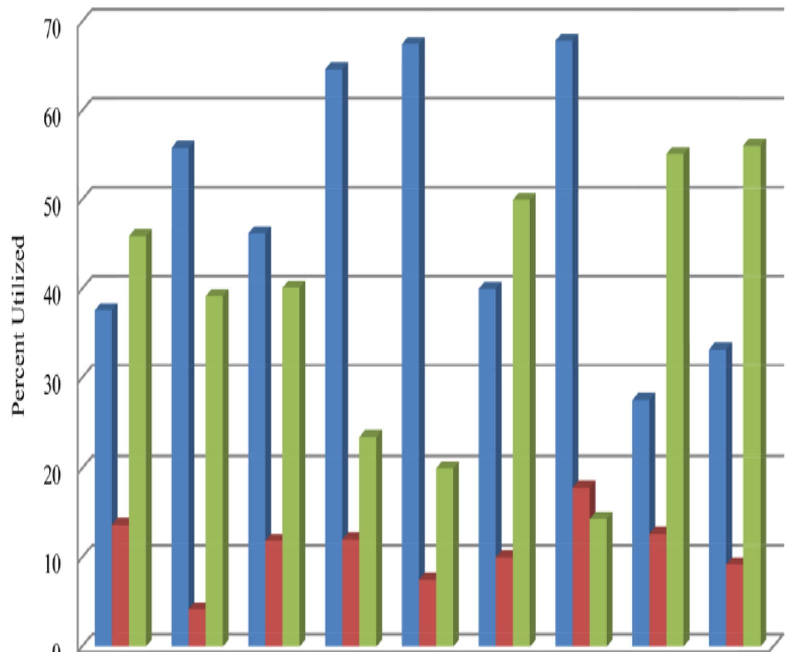

	2009/10 Amhara	2009/10 Benishan gul gumz	2010/11 Amhara	2010/11 Benishan gul gumz	2010/11 Oromia	2011/12 Benishan gul gumz	2011/12 SNNPR	2011/12 Amhara	2017/18 Amhara
Household Consumption	37.59	55.83	46.21	64.67	67.5	40	67.86	27.51	33.19
Seed	13.65	4.17	11.86	12	7.5	10	17.86	12.66	9.19
Sale	45.89	39.17	40.12	23.33	20	50	14.29	55.14	56.08

Fig. 9 Lupin utilization trends in regional level of Ethiopia. **Source (Habtemariam, Woldetsadik, and Belay.,2019)**

Nutritional composition of Lupin and Common usage of lupin in Ethiopia

Protein and Amino acid content

The protein content of legume seeds ranged from 17%–20% (dry weight) in peas and beans to 38%–40% in soybean and lupine this contrasts with the protein content of cereals, which is about 7%–13%, but It is similar to that of meats (18%–25%). Physicochemical study undertaken in Ethiopia on lupine by Tizazu & Emire (2010 2010) witnessed 37 and 43% protein composition for samples procured from Debre Tabor and Dembecha, respectively. This protein content is comparable to soybean which possesses about 40% protein and as for all legumes. Lupine bean protein is rich in lysine, leucine and threonine; and deficient in sulfur-containing amino acids (Joray *et al.*, 2007).

Lupine flour contains approximately 30–40% protein and effectiveness of its utilization is slightly lower than that of animal protein. The human diet which is high in lupine proteins affects a significant decrease in serum cholesterol, including the LDL (low-density lipoprotein, bad cholesterol) level and also the level of triglycerides and glucose and it also lowers the blood pressure. Lupine in addition to food decreases in glucose content in the blood was 6.7%, homocysteine 11.8%, and high sensitivity C-reactive protein (Hs-CRP) up to 18.3%(Nowicka et al. 2015).

Other report in Ethiopia Teshome et al. (2012) two bitter lupine collected from Amahara region (Gojjam) the protein content obtained for the samples Dangela (38.92%) and chagini(37.56%) which is comparable to the study(Kefale and Aberha, 2018) the protein content of sweet lupine grain had 31.65%. The amino acid in White lupine consist of 85% globulins and 15% albumins (Gulewicz et al. 2008). The globulin fraction contains 3 main proteins of varied amino acid composition: α-, s-, and γ-conglutin. γ-Conglutin containing more methionine, cytosine, and valine is a sulphur-containing amino acid that constitutes about 4% of the protein composition (Duranti et al. 2008). Some of them may have an allergenic effect (Guillamón et al. 2010).

Sweet Lupine contains two classes of proteins, albumins and globulins (Duranti et al. 2008). The globulins are the main seed storage protein and are classified into four families: α-conglutin, β-conglutin, γ-conglutin, and δ-conglutin (Gulewicz et al. 2008). These α, β, γ and δ-conglutins make up of 75% of the total protein in the seed (Duranti et al. 2008). The major limiting essential amino acids in lupine seeds are methionine, cytosine, valine and tryptophan (Doxastakis et al. 2002). The amounts of the other essential amino acids such as lysine, isoleucine, leucine, phenylalanine and tyrosine are comparable to the Food and Agricultural Organization (FAO) standards for amino acids of the ideal reference protein appropriate for adults.

Fat and Fatty acid

Legume seeds contain 2%–21% fat with beneficial composition of unsaturated fatty acids (FAs) as linoleic (18:2) acid (21%–53%)(Campos-Vega, Loarca-Piña, and Oomah., 2010). Total fat content in white lupine seeds was reported 8% (Andrzejewska et al. 2016) to 11.5% (Sujak, Kotlarz, and Strobel 2006). In the sub continental climate white lupine seeds are characterized by an approximately 8% lower fat content than in the Mediterranean climate (Annicchiarico et al. 2014). The fat content for Mexico lupine had high lipid content of up to 13% according the report of (García-López et al. 2001). The fatty acid of white lupine (Bitter lupine) cultivars (spp. *termis*) (52.2 %) had higher oleic acid than sweet cultivars (spp. *albus*) (44.9) 2.16%). Hodowla and Wiatrowo, (2016) identified in white lupine seeds also the following acids: myristic, pentadecanoic, palmitoleic, margaric, arachidic, eicosadienoic, eicosatrienoic, docosadienoic, and lignoceric at a content not higher than 1% each.

In general, lupine oil is characterized by a balanced fatty acid composition with total saturated fatty acids of 10% and total unsaturated fatty acids of 90%. The omega 3 fatty

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acid comprising exclusively of alpha linolenic acid are predominant in the most bean varieties, while omega 6 fatty acid (mainly linoleic acid) are abundant in the other legume types. The chickpeas have the highest monounsaturated fatty acids (MUFA) content (34.2 g/100 g), while butter beans have the highest saturated fatty acids (SFA) content (28.7 g/100 g), and kidney beans have the highest content of PUFA (71.1 g/100 g). Lupine contain a higher MUFA level (mainly oleic acid) and a lower SFA content(Kalogeropoulos et al.,2010).

Sweet lupine fat content affected by Geographical location from a continental location Europe had lower oil content (8.40 g 100 g^{-1}) than Mediterranean locations (11.08 g 100 g^{-1}) (Boschin et al. 2008). *L. mutabilis*, contains higher oil content (17 g 100 g^{-1} db.) than other lupin species (Hudson, Fleetwood, and Lewis 1983)and the content is comparable with the oil content of soybean (20 g/100g) .The fat content of the sweet lupine ranged from 7.75-8.5% according to the report done in Ethiopia (Kefale and Aberha, 2018). In terms of the fatty acid content of sweet lupine has high content of unsaturated fatty acids (UFA) and in *L. albus* the proportions of saturated fatty acid (SFA) and UFA are 12 (g 100 g^{-1} db.) and 88% of total lipid, respectively. Palmitic acid (9%) was the main component of SFA in *L. albus* while among UFA oleic acid (46%) linoleic acid (25%) and linolenic acid (12%) were found respectively (Hudson, Fleetwood, and Lewis 1983).

Carbohydrate

White Lupine grain contain various types of carbohydrates, mainly non starch carbohydrates (Khan *et al*. 2015) which are the most abundant in the grain. Study report in Ethiopia for two samples carbohydrate content of obtained 38.92% and 37.50%. A study by Jimenez-Martinez *et al*. (2003) reported the value for utilizable carbohydrate of raw *Lupinus albus* to be 26.80%.

Mineral content

Bitter lupine seeds are a rich source of macro and microelements their total content is 30–40 mg/kg (Prusinski, 2017). Among macro elements K, Mn, and Mg definitely prevail and among microelements Ca, Fe, and Na are dominant (Zelalem and Chandravanshi ,2015). Lower Ca content improves culinary properties of seeds and reduces the time of their overcooking (Tizazu & Emire 2010 2010).

Sweet Lupine like other legume seeds are also good dietary sources of minerals and some remarkable differences have been described in mineral contents either between lupine species or in comparison to other legumes. Lupine seeds have low levels of calcium and phosphorus but are similar or even better sources of trace minerals such as iron, zinc and copper when compared to other legumes (Wickramasinghe 2017). According to the study report done by Wickramasinghe, (2017)the mineral content of sweet lupine K(9.5-11.6), Mg(1.4-1.8), Ca(1.0-1.9), Mn(1316-1370), Fe(39-43), Zn(38-49). The biological utilization of dietary minerals is dependent upon several factors including antinutritional components such as phytate which may adversely affect mineral absorption. Therefore, the mineral content of a food product or diet should be determined together with its phytate content in order to have a better evaluation of its potential as a mineral source(Mohamed., 1995).

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Dietary fiber

Dietary fiber represents 40% of the kernel weight of white lupine which is a higher level than in most other legumes. The seed cover of *Lupinus albus* contains after the debittering process 89% of insoluble dietary fiber. The main component of the insoluble dietary fiber is cellulose (79%). Hemicelluloses and lignin remain at the levels of 7 and 14%, respectively. The ratio of soluble to insoluble fibers in legumes is comparable to that of grains (approximately 1:3 for both)of chickpea edible portion contain 17.4 g of total dietary fibers compared to 12.7 g for wheat(U.S. Department of Agriculture., 2002).

White lupine seeds are a valuable source of dietary fiber (mostly insoluble), which is higher than in soybean seeds (Písaříková and Zralý, 2010). In most *Fabaceae* plants the content of crude fiber ranges from 8% to 27.5%, and that of soluble fiber from 3.3% to 13.8% (Guillon and Champ 2002). The average content of total fiber is from 101 g/kg to 367 g/kg ((Tizazu & Emire ,2010) . Sweet Lupine consists of two main tissues, the seed coat (hull) and the kernel (cotyledons). Dietary fibers of lupine hull and kernel are very different. Lupine hull contains a very high amount of total dietary fiber (TDF) (8 g/100 g) mostly insoluble dietary fiber (Geigerová et al. 2017).The fiber content of bitter lupine of un processed 14.5% and Fiber content of sweet lupine un processed 18.3% reported in Ethiopia by(Abeshu and Kefale., 2017).

Vitamins

Lupine are good sources of B group vitamins especially thiamine (0.5 mg/100 g), riboflavin (0.4 mg/100 g) and niacin (4.0 mg/100 g) (Villacrés, Álvarez, and Rosell., 2020). Other vitamins presented in lupins include vitamin A (carotenoid) and vitamin E (tocopherol). Wang et al. (2016)reported the total carotenoid contents in lupins ranged from 53–229 μg/g. Total tocopherol contents in lupine varied from 9.9–52.5 mg/100 g (Martínez-Villaluenga, Frías, and Vidal-Valverde., 2006)**.** Compared to Chickpeas (arietinum) show the highest vitamin E activity (3mg/100g seeds), followed by soybean (1.8mg/100 g) and lupine, broad beans, and peas (with values ranging 1.25–1.0mg/100 g), whereas lentils and species of Phaseolus genus have much lower contents (0.6mg and 0.3mg/100 g seeds, respectively) Table (1 and 2).

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Table 1. Comparison of Lupine nutritional component with other legume.

Nutrients	Unit	Lupin	soyabean	peas	Chieck pea	White bean
1.protien	g	39.1	36	8.34	8.86	9.73
2.Fat	g	11.2	19	0.39	2.59	0.35
3.carbohydrate	g	21.5	30	21.1	27.42	25.09
4.dietary fiber	g	10.0	10	8.3	7.6	6.3
Mineral						
1.Ca	mg			14	49	90
2.Fe	mg	6.01	16	1.29	2.89	3.7
3.Mg	mg	8.9	280	36.0	48	63
4.Zn	mg	2.1	4.8	1.0	1.53	1.38
Vitamin						
1.vatiamin C	mg	1.1		0.4	1.3	0.0
2.Thaamin	mg	0.134	0.89	0.19	0.116	0.118
3.Reboflavin	mg	0.053	0.87	0.056	0.063	0.046
4.Nacian	mg	0.495	1.6	0.89	0.526	0.140
Lipid						
1.Total saturated	g	10.6	2.8	.054	0.269	0.091
2.Total unsaturated	g	75.5	15.6	.246	1.73	.183
Amino acid						
1.Glutamine	mg	67.31	8.0	16.9	16.5	17.6
2.Asparagine	mg	35.33	11.0	10.73	12.6	9.25
3.Serine	mg	18.21	5.2	5.05	5.56	4.13
4.Arginine	mg	35.64	7.2	5.29	8.3	7.59
5.Leucine	mg	24.7	7.1	6.63	7.47	6.44
Referance		Proximate;(Biadge and Yadesa.,2017) ,Mineral and fatty acid; (Getachew et al.,2016),amino acid; (Likawent et al., 2012), Vitamin;(Çakir et al. 2019)	(Cristina Martínez-Villaluenga et al. 2006)Amino acid ;Guillamue et al.,2017	(Çakir et al. 2019)amino acid; (Grela et al. 2017)	(Çakir et al. 2019)amino acid; (Grela et al. 2017)	(Çakir et al. 2019) amino acid; (Grela et al. 2017)

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Table 2: Comparison of lupine protein, amino acid and protein digestibility to high protein and amino acid content.

Protein, Amino acid and protein Digestibility	Lupine(mg/Kg)	Egg(mg/Kg)	Meat(mg/Kg)	DRI(FAO/WHO) for adults(mg/Kg)
1. Protien content (%)	39.1	48.6	24.8	64
2. Methionine	2.03	18.7	18.2	10.4
3. Threonine	12.41	31.3	34	15
4. Valine	13.61	37.4	37.9	20
5. Iso lucine	15.27	35	35.5	26
6. Leucine	24.55	54.3	61.3	39
7. Phenylalanine	13.24	26.2	30.9	25
8. Histidine	8.18	13.9	31.7	12
9. Lysine	16.16	46.3	73.2	30
10. Arginine	33.37	43.2	59.5	
11. Asparagine	34.72	61.5	69.3	
12. serine	17.78	50.9	29.4	
13. Glutamine	66.05	77.2	103.4	
14. Glycine	13.71	17.6	42.4	
15. Alanine	11.0	31.5	46.0	
16. Protein Digestibility	78.55	70.03	80.0	
Reference	Protien, amino acid; (Likawent yeheyis et al. 2012), Protien Digestablity;(Embaby., 2010)	Protien, amino acid;(Clement and Marcq., 1973), Protien Digestablity;(Msarah and Alsier., 2018)	Protien, amino acid;(Herzig ,.2017), Protien Digestablity;(Farouk et al. 2019)	DRI;(WHO/FAO., 2002)

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Table 3. Different Type of products developed from Bitter and Sweet lupine in Ethiopia

Product Name	Major Composition/Ingredients	Reference
1. Injera	Teff(Magna) variety and sweet lupine(Welela) Variety flour used in different ratio and Injera prepared using Conventional method.	Yegrem and Temesgen, 2020
2.*Shero,Nefero,Kolo*	*Sweet lupine recipe: (100%) sweet lupine used for recipes (Shero,Kolo,Nefro). Shero prepared according to Pea shero preparation method, Nefro(Cooked Food), Kolo(Roasted Food).*	Biadge K and Esayas A ,2018
3.Bread	Wheat(Denda) Variety flour and Sweat lupine(Welela) Variety used in different ratio for bread preparation.	Biadge and Bethel, 2020
4.Bread	Sweet lupine, sweet potato and Wheat used in different ratio for Bread Preparation.	Tegenge, 2018
5.Snack	Soaked lupine (review report)	Hibstu Azeze., 2016
6.Snack	Bitter lupine, maize and wheat by different ratio using Extruder.	Adem et al. 2019

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Anti-nutritional Content of Bitter and Sweet Lupine

Anti nutritional factors are compounds presented in food or feed which reduce nutrient utilization including intake, digestion and absorption (Inyang Udousoro, Ekop, and Johnson Udo.,2013). Anti nutritional divided into two main groups: heat labile compounds and heat stable compounds. Heats labile anti nutritional factors compose of saponins, lectins and proteinase inhibitor which are destroyed or reduced during thermal processing. Heat stable group includes phytic acid, polyphenol (mainly tannin), raffinose family oligosaccharides and quinolizidine alkaloids (D'Mello.,2004). Main anti nutritional factors in sweet lupin is raffinose family oligosaccharides (RFOs), phytic acid and polyphenols. Lupin contains low amount of lectins and trypsin inhibitors compared to other legumes such as cowpea, kidney bean and soybean (Cabrejas et al.,1995).

Alkaloids

Quinolizidine alkaloids (QAs) are a family of about 100 bitter components secondary metabolites of a bicyclic, tricyclic, and tetracyclic structure (Sujak, Kotlarz, and Strobel 2006).

In lupine the reported total alkaloid content varies on average the lower total alkaloid content is reported in the range (0.186 g/100 g) - 2.8 g/ 100 g dry weight base. Regarding the diversity of alkaloids in the major lupin species the principal alkaloid reported is lupanine ($C_{15}H_{24}N_{20}$).

The Bitter lupine concentration of alkaloids in the raw samples 2.46% and 2.26% reported in two different location in Ethiopia by (Teshome et al. 2012) .

Total alkaloid content in sweet white lupine cultivars has been significantly reduced in the process of domestication and breeding and does not currently exceed 0.02% (Prusinski, 2017).Most alkaloids may cause cramps, vomiting, and even death as a result of the respiratory system paralysis. Alkaloids also negatively affect the central nervous system in mammals, though in very low doses they may have a stimulating effect, while in high doses an inhibiting effect. In humans too high dosage, especially of lupanine and sparteine, may also cause trembling, arousal, and convulsions leading to blurred vision, dry mouth, nervousness, and bad mood (Prusiński, Borowska, and Kaszkowiak, 2012).

Phytic acid

Phytate commonly found in cereal grains, legumes and oilseeds. Phytate is formed during seed maturation accompanied by other storage substances such as starch and lipids (Vashishth, Ram, and Beniwal.,2017). Physiological functions of phytate in the seed include providing phosphorus, inositol phosphate and cations storage relating to the formation of cell walls, and providing antioxidative potential against free radicals (Johnson et al.,2015). Phytate is considered an anti-nutritional factor because it can bind directly or indirectly with protein, starch and minerals, resulting in poor bioavailability of these nutrients. The binding properties of phytate change solubility, functionality, digestibility and absorption of the nutrients (Muzquiz et al. ,2012).

Phytate is indigestible by human and monogastric animals since they have no or limited intestinal phytase enzyme(Porres et al.,2006). Reduce the bioavailability of mineral components in monogastric animals through cation chelation (Zn, Mg, Ca, Fe, K, and Mg) to non absorbable

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phytynians. Phytic acid content in white lupin seeds (0.03%) is significantly lower than in soybean from 1.54%. In the studies of (Martínez-Villaluenga, Frías, and Vidal-Valverde., 2006)0.025–0.044% of phytic acid found in white lupin seeds. Phytic acid contents in lupine reported 0.1–1.7% depending on species (Embaby.,2010).

Raffinose family oligosaccharides (RFOs)

RFOs are low molecular weight oligosaccharides that are soluble in water and water alcohol solutions (Fritsch, Vogel, and Toelstede.,2015). Raffinose, stachyose, verbascose and ajugose are mono-, di-, tri- and tetra-galactosyl derivatives of sucrose, respectively. Raffinose is a trisaccharide composed of galactose, glucose, and fructose. Stachyose is a tetrasaccharide composed of two galactose units, glucose, and fructose. Verbascose is a pentasaccharide composed of three galactose, one glucose and one fructose units. Ajugose is a hexasaccharide composed of four galactose, one glucose and one fructose units. In plants, RFOs are the most abundant soluble carbohydrates ranking next to sucrose (Martínez-Villaluenga, Frías, and Vidal-Valverde., 2006). RFOs are synthesized and accumulated in storage organs, such as seeds and tubers during their development process (Martínez-Villaluenga, Frías, and Vidal-Valverde., 2006). Raffinose is found in all legume seeds to some extent. The major RFO in most legume seeds is stachyose, while verbascose is the predominant RFO in some species (Peterbauer and Richter., 2001). Lupin is the richest source of RFOs ranging between 5.1–16.1% which varies depending on the species (Lucas et al.,2015).

Sweet lines of white lupin from California contained 5.3% of oligosaccharides, including stachiosis (2.8%), sucrose (1.8%), raffinose (0.4%) and verbascose (0.3%), while in Australian cultivars constituted 5.85–7.41%(Mohamed, 1995). Depends on cultivar and also on the place of lupine cultivation more oligosaccharides were found in Germany (10.3%) than in Argentina (8.6%) or California (5.3%) (Mohamed, 1995). Their negative nutritional effects include flatulence and abdominal discomfort due to the anaerobic fermentation in the large intestine and interfering some nutrients digestion and absorption (Gulewicz et al.,2008)

Phytochemicals

Phytochemicals are an important group of plant derived compounds which is responsible for functional food effect (disease protection ability) of plant foods tea, wine, fruits, vegetables and cereals. Phytochemicals are classified into different groups based on their chemical structure, namely polyphenols, phytoestrogens, terpenoids, carotenoids, phytosterols and phytohemagglutinins (Khan et al. 2018). Generally the major phenolic compounds identified in lupin species belong to subclass flavones, phenolic acids and isoflavones .Flavones, phenolic acids and isoflavones are present in 76%, 19% and 4% of the total identified phenolics, respectively (Dueñas et al. 2009). Polyphenols are one of the largest groups of secondary metabolites in plants.

These compounds are found in numerous plants including cereals, fruits, legumes and vegetables. Polyphenols are synthesized in plants as responses to ecological and physiological stresses such

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as insect attack, pathogen Infestation and UV radiation (Cristina Martínez-Villaluenga et al. 2009). In legumes the main polyphenols are flavonoids, phenolic acids and tannins.

Tannins.

Phenolic compounds produced at the end of plant maturity and accumulated mainly in seed coats constitute natural protection against diseases and pests and show antioxidative, antifungal and antibacterial properties. Jayasena, Khu, and Nasar-Abbas. (2010)found small amounts of them in white lupin seeds (0.23–0.52%), while Siger et al. (2012) detected slightly above 2 mg/100 g in dehulled raw seeds. During seed fermentation, tannin content increased significantly up to about 8 mg/100 g, whereas after extrusion it slightly decreased.

Table 4. Summary of anti nutritional contents in lupine study done in Ethiopia compared to other country.

Referance	Alkaloid	phytate	Tannin	Collection site
Tizazu Habite et al.,2014	2.29	2.68	13.65	Demebecha and Deberetabor, Amahara region,Ethiopia
Paulose Getachew et al.,2012	2.46	1.44		Dangela, Chagini, Amahara region, Ethiopia
Yadesa A and Biadge K.,2017	1.76			Holeta, pulse breeding department, Ethiopia
L.yeheyis et al.,2011	1.17			Mecha, Sekela, Amahara region, Ethiopia
Ahemed et al 2015		2.7	1.25	Turkish
Embaby, 2010		1.36	7.53	Egypt

Effect of processing on the anti-nutritional content of lupine

(Habtie, Admassu, and Asres., 2009)reported Roasting is a common practice of legume processing all over the world. The process is meant to induce appealing flavor reduced moisture content of the product inactivate thermo labile ANFs and produce a better acceptable product. Roasting reduced the levels of alkaloids by 34.22 % in lupins. The reason for reduction of alkaloid concentration is likely to be due to the volatile nature of lupin alkaloids, particularly when they are present in their free (basic) forms. 19.78 % phytic acid reduction observed after dry roasting of seeds. Roasting also least reduced the levels of tannins (0.73 % in lupine samples). Roasting has been reported to increase the antioxidant activity and inactivate the ANFs of sesame seed flour (Karamać et al. 2018).

Extrusion processing is a high temperature short time process and the capability has been beneficially used to inactivate the enzymes destroy ANFs kill microorganisms and improve digestibility. Extrusion cooking reduce the levels of alkaloids, phytic acid and tannin the lupin samples. This processing method also reduced the levels of tannins and alkaloids by 14.21 and 77.55%, respectively in lupine sample. Extrusion cooking has been reported to inactivate ANFs of binary mixtures composed of bitter lupin/maize (Placak.,1953).

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Aqueous thermal treatment reduced the alkaloid level lupine by 98.69%. The alkaloid concentration after aqueous thermal treatment reached 0.03% lupine samples, which is three times higher than the safety limit 0.01% (Authority, Australia New Zealand Food.,2001).The method was found to be the best processing method for reduction of the concentration of phytic acid from the lupin samples. Reduction in phytic acid concentration 28.36% reported in lupine. The treatment is also effective in reducing the levels of tannins. It reduces tannins by 56.41% lupine samples. Alkaline thermal treatment reduce the levels of QAs from 2.29% to 0.01%, which is a 99.56% Jiménez-Martínez et al. (2001)reported that a final QA concentration of 0.002% in debittered lupine seeds (L. campestris) after alkaline (NaHCO3) thermal treatment, which has represented 99.9% QA elimination. Torres et al. (1980) found that the application of alkaline thermal treatment (using an unspecified alkali) reduced the total QAs by 98.6%.

The concentration of alkaloids after alkaline thermal treatment equals to 100 mg/kg (0.01%) in lupine sample that is below the maximum limit of 0.02% recommended by the Australia-New Zealand Food Authority (2001). The tannin concentration of the lupine sample reduces from 13.65 g/kg to 0.95g/kg, a 93.04%. Shimelis and Rakshit (2007)reported that soaking of improved kidney bean varieties of Ethiopia in NaHCO3 solution, followed by cooking and autoclaving significantly reduced tannins, phytic acid, lectins, trypsin inhibitors, phytohaemagglutinins, saponins, W-galactosides and increased protein digestibility.

According to Abeshu and Kefale. (2017)reported Alkaloid content of the lupine reduced in soaked, cooked, fermented and germinated, but it was highly influenced by cooking and soaking methods. The alkaloid content of sweet lupine shows decreasing trend to each processing methods which ranges from 1.76% to 0.31%. The cooking and soaking methods were more effective than the others in decreasing alkaloid content and improving the nutritional quality of the lupine (Umaru et al. 2007).

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Table 5. Effect of Processing to the Antinutritional content of lupin in Ethiopia.

Processing Method	Anti nutritional content						References
	Bitter			Sweet lupine			
	Alkaloid	Phytate	Tanine	Alkaloid	Phytate	Tanine	
1. Germination	6.03-5.99	Not studied	Not studied	1.76-1.51	Not studied	Not studied	Abeshu and Kefale., 2017
2. Cooking	6.03-4.6	Not studied	Not studied	1.76-0.76	Not studied	Not studied	Abeshu and Kefale., 2017
3.Fermentation	6.03-4.66	Not studied	Not studied	1.76-0.59	Not studied	Not studied	Abeshu and Kefale., 2017
4.Extrusion cooking	2.29-0.56	2.68-2.1	13.65-11.71	Not studied	Not studied	Not studied	Habtie, Admassu, and Asres., 2009
5.Aqueous thermal Treatment	2.29-0.03	2.68-1.92	13.65-5.95	Not studied	Not studied	Not studied	Habtie, Admassu, and Asres., 2009
6.Alkaline thermal treatment	2.29-0.01	2.68-2.04	13.65-0.95	Not studied	Not studied	Not studied	Habtie, Admassu, and Asres., 2009
7.Soaking	6.03-3.78	Not studied	Not studied	1.76-0.31	Not studied	Not studied	Abeshu and Kefale., 2017
8.Roasting-soaking	2.46-0.83	1.44-1.33	Not studied	Not studied	Not studied	Not studied	Teshome et al. 2012

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CONCLUSION

Lupine is the oldest crop species of the kind and may constitute a potential source of protein. The high biological value of proteins and important sources of amino acids positively affect the physiological condition of the human body. Lupine oil has desirable ratios of omega-6 to omega-3 acids for consumption purposes. Lupine seeds are also a valuable source of dietary fiber both soluble and insoluble with its well known beneficial effect on reducing the cholesterol level and on susceptibility to heart disease. Soaking, extrusion cooking, alkaline thermal treatment and Aqueous thermal treatment are efficient methods to reduce ant nutritional content of lupine below the limit. In Ethiopia sweet lupine and bitter lupine used in the production of different kinds of functional foods such as in the production of food products like Bread, snack, Injera, *Shero, Kolo and Nefro.*

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