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ABSTRACT BOOK

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LUPIN IN RUMINANT DIETS B. R. Moss[1], J. C. Lin[1], D. W. Reeves[2], S. Kochapakdee[1], P. L. Mask[3] and E. van Santen[3].

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Lupin (Lupinus sp) have been fed as either grain or forage to different ruminants throughout the world. Sweet white lupin (L. albus L.) seed has potential as a protein-energy feed with a moderate crude protein (30-40%) and fiber [acid detergent fiber (ADF), 14-18%; neutral detergent fiber (NDF), 21-25%] content with energy values similar to soybean [Glycine max (L.) Merr.] meal. Decreased dry matter (DM) intakes have occurred in both dairy and beef cattle (Bos taurus) as well as decreased milk production in dairy cattle when soybean meal was replaced with raw lupin seeds as the protein source. In studies in which 75-100% of soybean meal was replaced with lupin seed, similar intakes and production values were obtained. Different results with seeds have been attributed to particle size as grinding lupin has improved milk production. Decreased milk protein may occur when cows are on lupin grain diets. Lupin seed ruminal degradation is high (>60%), but protein supplements of low degradability are considered desirable for maximum amino acid availability. Heat treatment decreases the ruminal digestion of protein in lupin seed and increases total amino acid flow to the duodenum. However, studies indicate that heat treatment is not always consistent in improving performance for beef or dairy cattle. Whole plant lupin may be a very beneficial forage source, but information on this aspect is sparse. Grazing lupin has been successful with sheep (Ovix aries) and subjective observations indicate deer (Odocoileus virginianus) relish lupin but grazing limits management options. Silage is a good option resulting in high yields (20.2-33.6 Mg ha^{-1} of 35% DM silage). Ensiling is a challenge because of the high moisture content of the whole plant (71-78%), slow moisture loss from the stem coupled with leaf abscission and the difficulty in determining the optimum maturity for harvest which affects ensiling properties and nutrient values. The pH of lupin silage decreased rapidly and developed a desirable volatile fatty acid content when ensiled in laboratory silos. Whole plant nutrient content varied widely with (silage) values (% of DM) of: crude protein (CP), 12-18%; soluble protein, >55%; ADF, 33-43%; NDF, 38-50% and DM digestibility, 56.0-66.5%. Beef cattle fed lupin silage had similar gains as those on grass silage. Milk production and feed intake were similar for cows receiving total mixed rations with either lupin or corn silage as the base. Less DM intake but similar milk yields with no difference in composition occurred when cows received either lupin or corn silage based diets. Blood and milk urea nitrogen content did not

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differ for cows on corn or lupin silage based diets. Lupin provides an excellent opportunity for high quality forage, but further evaluations are needed.

Abbreviation key: **ADF** = acid detergent fiber, **BUN** = blood urea nitrogen, **CP** = crude protein, **DM** = dry matter, **DMI** = dry matter intake, **EE** = ether extract, **FCM** = fat-corrected milk, **IVDMD** = in vitro dry matter digestibility, **Mg** = megagram, **MJ** = megajoule, **ME** = metabolizable energy, **MUN** = milk urea nitrogen, **NDF** = neutral detergent fiber, **SBM** = soybean meal, **VFA** = volatile fatty acid.

INTRODUCTION

Livestock production is the most important value-added industry in the United States (Parker, 1990) and ruminants constitute a major portion of the livestock industry in the United States as they do worldwide. Most ruminant diets include a large proportion of forages regardless of their production function. For optimum production, some ruminants such as lactating dairy cows require quality forage as well as energy and protein dense grain mixtures. Lupin has the potential of meeting nutrient needs by incorporating either the seed or forage into ruminant diets. Lupin has been used as a livestock feed for many years and has garnered much interest with the development of varieties with reduced alkaloid content. Both seed and forage have been utilized in ruminant diets worldwide, but data relative to forage are limited. Although there are exceptions, most lupin species used for ruminant feeding are cool-season annual species. Thus lupin may provide a locally grown forage or protein supplement during times (e.g., winter months in the Southeast U.S.A.) or geographic locations wherein cooler climates limit or prevent crops such as soybeans from being grown. The feeding value of sweet white lupin will be the major focus of this paper.

SUPPLYING THE NUTRIENT REQUIREMENTS OF RUMINANTS.

Many nutrients are required if ruminants are to function satisfactorily. Although minerals and vitamin needs must be considered, energy and protein are the most important in the formulation of diets. As illustrated in Table 1, the amounts of these nutrients will vary with the function or category of the ruminant.

Annual milk yield of Holstein cows in the U.S.A. exceed 9000 kg and many herds average over 11,000 kg of milk per year. Similar production levels are achieved worldwide and high production occurs in all breeds of dairy cattle. In order to achieve such annual production, daily milk yield surpasses 40 kg over much of the lactation. Even lower milk production requires a greater energy and protein requirement than for most categories of ruminants. However, meeting the nutrient needs of any ruminant is critical.

Exceptions exist, but many harvested forages are too low in protein to meet ruminants' requirements for satisfactory production. Energy and protein requirements of beef cattle and sheep (Table 1) can be provided with only good quality forage such as alfalfa (Medicago sativa), but the protein content of various forages such as corn (Zea mays) silage and mature coastal bermuda grass (Cynodon dactylon) are low (Table 2). With such forages, beef cattle and sheep require supplemental protein to meet their needs. Lactating dairy cows have high protein and energy needs (Table 1) yet most grains [e.g, corn, barley (Hordeum vulgare)] and forages fed are low in protein (Table 2). To reduce production costs, producers are continually seeking economical protein supplements to substitute for soybean meal, the most prevalent protein supplement in most areas.

LUPIN SEED IN RUMINANT DIETS.
Sweet white lupin seed has potential as a substitute protein source for soybean meal (SBM) or other protein supplements. Lupin seeds used in recent studies (Benchaar et al. 1994; Guillaume et al., 1987; May et al., 1993; Murphy and McNiven, 1994; Robinson and McNiven, 1993, Singh et al., 1995) contained 30-40% CP , 7.3-11.0% ether extract (EE), 17.2-27.4% NDF and 10.1-18.8% ADF. These CP and EE values are very similar to those previously reported (Ballester et al., 1980; Emile et al., 1991; Hill, 1980; Hove et al., 1978) for sweet lupin. The CP content is moderate compared to most SBM but lupin seed contain more protein than other supplements such as corn distillers grains (Table 2). Maintaining sufficient fiber (19-21% ADF; 21-28% NDF) in lactating dairy cow diets is often difficult due to the need for energy and protein dense diets. The moderate ADF (10-19%) and NDF (17.2-27.4%) content in lupin seed may assist in meeting the fiber needs of ruminants. Increasing fibrous feeds into diets reduces the energy concentration of the feed. However, the lipid content (7.3-11.4%) supplies energy which may well exceed that of other feeds with moderate CP content. Few energy values are available for lupin seed. Murphy and McNiven (1994) gave metabolizable energy (ME) values of 13.1 MJ kg^{-1} for lupin seed and a corresponding value of 12.7 for SBM. The lupin value is less than those determined using sheep (Margan, 1994) with values of 15.7 and 14.4 MJ kg^{-1} for production and maintenance levels when lupin seed was feed alone or 14.0 MJ kg^{-1} as estimated by difference when fed with wheaten hay. Lupin seed is normally considered a viable protein and energy source for ruminants, but may have limited value as a protein source for sheep. Lupin seed is a good energy source and has a positive effect on ovulation rate for sheep but nitrogen retention from lupin seed is low (Margan, 1994). The rapid rate of rumen protein degradation and the possibility of a deficiency of sulfur to assure microbial use of the available nitrogen were posed as possible causes for the lack of protein utilization. Providing a supplemental sulfur may (Peter et al., 1987; White et al., 1990: as cited by Doyle et al, 1992) or may not (Doyle et al., 1992) improve performance. The mineral content of lupin seed are within the same range as SBM except for manganese content which is unusually high (700-1900 mg kg^{-1}). When lupin are used in mixed

diets, manganese concentration is normally below the tolerance level of 1000 mg kg^{-1} (NRC, 1980).

Although lupin seeds are considered a satisfactory protein source for dairy cattle, the effects on feed intake, milk production and milk composition have not been consistent (Table 3). Several researchers (Guillaume et al., 1987; Robinson and McNiven, 1993; Singh et al. 1995) observed reduced dry matter intake (DMI) with dairy cows consuming diets containing lupin seeds but others (Emile et al., 1991; May et al. 1993) reported that lupin seed did not influence dry matter intake (DMI). Milk yield did not differ significantly for cows on diets containing either SBM or raw lupin seed in these studies although cows in one study (Guillaume et al., 1987) tended to have lower production when receiving lupin seed. In another study (May et al., 1993), cows which received 75% of the supplemental protein as lupin seed produced more 3.5% fat-corrected-milk (FCM) than cows receiving SBM as the entire protein supplement.

The form of lupin offered may well influence the performance of ruminants. Grinding has been considered beneficial as the lupin hull is considerably thicker than that of soybean. Most studies have used ground or rolled lupin seed but some producers believe that milk production has been similar on either whole, ground or rolled. May et al. (1993) fed cows diets with 17% (DM basis) either ground or whole lupin. The form of feeding lupin did not affect DMI but cows consuming the ground lupin produced 2.0 kg d^{-1} more milk than cows fed whole lupin. Up to 26% of whole lupin seed DM may be lost in the feces (Valentine and Bartsch, 1986) and digestibility is decreased. May et al. (1993) reported DM and CP in situ rumen degradability values of 18 and 3%, respectively, for whole lupin versus 82 and 91% for ground seed. Whole tract degradablity of CP was 60% for whole lupin and 99% for ground lupin. However, they attributed differences of milk persistency to available energy in the ground lupin diet. In a companion study (May et al., 1993), cows produced similar milk yields but more milk fat and 3.5% FCM on diets containing 16.5% whole lupin than on diets containing 12.0% whole soybean. The authors indicated that the increased FCM and milk fat production could have been due to higher fiber content in lupin diets. Emile et al. (1991) reported that lupin must be ground for dairy cattle, but growth and intake were not affected in young bulls receiving diets containing with either whole or ground lupin seed.

Feed ingredients may affect milk composition which in turn affects milk price in most areas. Inclusion of lupin as a substitute for SBM did not alter milk fat in most studies, but milk protein content was depressed in several studies (Guillaume et al.1987; Robinson and McNiven, 1993; Singh et al, 1995). This and other aspects of reduced production may be due to the high solubility and/or rapid degradation of lupin protein in the rumen. If this occurs, protein utilization for microbial synthesis and availability to the animal, either as microbial or undegraded feed protein, could be reduced.

Benchaar et al. (1994) reported a solubility (artificial saliva) of 29.5% and a ruminal degradation of 64.2% for raw lupin seed. Several other studies (Benchaar et al. 1991; Hume, 1974; Freer and Dove, 1984) have also found rumen protein degradability to be relatively high compared to other feeds. Hume (1974) reported 65% degradability for lupin seed compared to 39% for SBM. However, Wright et al. (1989) reported no difference in CP degradation among SBM or lupin treatments in a continuous culture system to evaluate fermentation by rumen bacteria. Singh et al. (1995) also reported no difference in the rate of rumen degradation or undegraded intake protein between lupin seed and SBM. The lupin used in their studies were coarsely ground whereas other studies normally ground feed to pass through a 1 or 2 mm screen. They attributed differences in results to the increased particle size which decreases ruminal CP degradation (Kung et al. 1991).

Heating feeds, especially oilseeds, has been used to increase the amount of protein which is undegraded in the rumen. By treating feeds in this manner, the amount of dietary protein and amino acids presented to the lower intestine may be increased. Extrusion and roasting are two processes used to evaluate the effect of heat on lupin. Roasting lupin (105°C exit temperature) reduced the N solubility in buffer from 69.8% in raw lupin to 35.8% in roasted lupin (Murphy and McNiven, 1994). The CP degradation and rate of degradation was also decreased from 82.3% and 9.2% h^{-1}, respectively, for roasted lupin compared to 86.7% and 11.9% h^{-1} for raw lupin. Charlois cross steers (235 kg liveweight) fed either raw lupin, roasted lupin or SBM at 6.5% of a grass silage DM improved growth over silage alone during the growing phase. Gains of steers were not different on diets receiving raw or roasted lupin but steers receiving raw lupin grew slower than those receiving SBM. No difference occurred during the finishing phase or for overall performance for the combined period of the growing and finishing phase. The influence of roasting lupin on milk production is not consistent (Table 3). Robinson and McNiven (1993) reported that roasting had no effect on milk production or milk fat although roasting increased the concentrations of long-chain fatty acids in the milk fat. In a subsequent study (Singh et al., 1995), roasted lupin increased milk production, but milk protein was depressed relative to that from cows on SBM containing diets. The milk protein depression may be due to the fat content of the seed as some oilseeds cause such a depression (Moss, 1990a).

Heating oilseeds through extrusion has gained considerable interest during the last few years. Optimum temperature is considered to be 195°C (Benchaar et al. 1994). Emile et al. (1991) reported that extrusion reduced rumen protein degradation and improved milk production (26.7 kgd^{-1}) compared to raw ground lupin seed (24.2 kgd^{-1}) or SBM (25.3 kgd^{-1}). Johnson et al. (1986) reported similar apparent digestiblities [DM, EE, NDF, non structural carbohydrates (NSC)] and daily gains in cattle fed diets containing either extruded lupin seed or SBM. Benchaar et al. (1991) noted no difference in bacterial protein synthesis between diets containing either raw whole or extruded whole lupin seed although the nitrogen degradation was reduced from 64% to 39% for extruded seed. Dietary nitrogen flow to and absorption from the small intestine were greater for extruded seed than raw seed. In a subsequent paper (Benchaar et al. 1994), they reported similar ruminal degradation of dietary nitrogen, but less amino acids flowing to the abomasum and less absorption from the small intestine. The apparent digestion of amino acids was also less in cows consuming raw lupin seed compared to those fed extruded lupin seed.

Results with other undegradable protein supplements, including heated proteins, have been mixed (Santos and Huber, 1995). Since the advent of feeding rumen undegradable protein, the use of animal by-product supplements has been preferred as the undegradable protein source. The current concern about the link between meat and bone meal protein supplement and Bovine Spongiform Encephalopathy, often referred to in the media as the Mad Cow Disease, has changed recommendations. The livestock industry is seeking different protein supplements such as lupin seed, especially those which can be heat treated to increase rumen undegradability.

THE LUPIN PLANT AS A FORAGE SOURCE FOR RUMINANTS.

Including some forage in the diets of ruminants is essential regardless of the price or availability of feeds. Diets containing high amounts of grain are common with some categories of ruminants (e.g., high producing dairy cows, finishing beef animals) but a minimum amount of forage is necessary to prevent digestive upsets and, in the case of dairy cows, to maintain a normal milk fat test. Good quality forage is considered to be a major factor in many ruminant diets, but availability of such forage is often limited. Lupin have the potential as a forage crop in many locations. Yields of 7 to 12 Mg DM Ha^{-1} are feasible (Sheldrick et al. 1980; van Santen et al., 1993). However, lupin forage data are limited.

For some time, blue lupin (<u>Lupinus angustinfolius</u> L.) was considered the forage crop preference (Sheldrick et al., 1980), but other lupin have garnered more interest recently. Grazing lupin has been of interest in New Zealand (Burtt and Hill, 1990). and perennial Russell (a hybrid) lupin has been successfully used as a grazing crop for sheep (Hill, 1993). Although alkaloid concentration was about 2% in the forage, sheep readily consumed the forage. Nitrogen content was high in the forage throughout the growing season but the concentration in various plant parts differed during the growing season. The fiber (NDF) content in the whole plant increased with maturity (0.21% increase per day) with a corresponding decrease in digestibility from about 75.4% to 57.1% in the whole plant. Leaf DM digestibility was high (>84%) throughout the growing period with no decrease in digestibility with increasing maturity. Digestibility of stem and petiole fractions factor decreased with maturity. This digestibility pattern is very similar to that for alfalfa and emphasizes the advantage of retaining leaves if forages are harvested (Moss, 1990b). The high digestibility of lupin in early maturity is similar to that reported by Aksland et al. (1991) for whole plant lupin (L. albus). Grazing lupin is not currently practiced to any degree in the United States although use of blue lupin as a winter grazing crop was recommended several decades ago in the Southeastern United States (Forbes and Wells, 1963). From a nutritional standpoint, the sweet white lupin plant could certainly be a satisfactory forage to graze, but whether grazing could be tolerated is not known. White tail deer invaded and grazed our winter lupin research crops with regularity and apparent relish when other forages were available.

Occasional comments are made relative to hay in conjunction with lupin. Haying is possible (Allen et al., 1978) and as with all crops, maturity influences the nutrient content (NRC, 1971). The high moisture content at desired maturity and slow moisture loss coupled with leaf abscission causes nutrient loss and difficulty with haying of any crop with large stems. Thus, haying lupin forage has limitations.

Preserving crops as silage is a often a good option because (1) field losses are low with maximum retention of leaves (2) harvesting is not overly affected by weather (3) silage is much easier than hay to use in "total mixed rations", a feeding method used on the majority of today's dairies (5) ensiling often blends into double cropping more readily than other methods of harvest.
Murphy et al. (1993) compared grass [Timothy (Phleum pratense) and Kentucky Bluegrass (Poa pratensis) mixture] and lupin silage supplemented with barley or potatoes (Solanum tuberosum) as a feed for beef cattle. Lupin plants were harvested at an immature stage (second-third pod set). Steers were fed one of the silages with either rolled barley or potatoes as a supplemental energy source. The lupin silage had a DM content of 28% and values (% DM) of 16.0, 47.8 and 37.5% for CP, NDF and ADF, respectively. The NRC (1971) value for CP is higher (18%) but a similar ME value (8.13 MJ kg^{-1}) is listed for "early bloom" lupin silage. Soluble nitrogen is of concern with most "hay-crop" silages and is a factor to consider with lupin silage. However, the amount in this study was within the range considered satisfactory (protein N of 35-60%; Thomas and Chamberlain, 1982 as cited by Murphy et al., 1993). There were no differences in gain, carcass weight, dressing percentage or backfat for steers fed the different silages. The DM degradation rate did not differ for the silages, but lupin nitrogen degraded at a faster rate than grass. The effective degradation of nitrogen was 63.8% for grass vs. 79.1% for lupin.

Silage evaluation is one aspect of a multi-disciplinary research team approach to improving the economic viability of farms in the southern region of the United States. Cropping systems utilizing winter-grown lupin in conjunction with tropical (Zea mays L.) and pearl millet [Pennisetum glaucum (L.) R. Br.], both drought-tolerant summer crops are being investigated by scientists in

Alabama, Florida and Georgia. Removal of these crops as silage allows earlier removal of crops than if they were harvested for grain and thereby enhances the ability to provide optimum crop yields in a double cropping system. Lupin silage has been evaluated in laboratory silos and as a feed for lactating dairy cows as a part of this study.

Laboratory silo evaluations. Fall planted lupin (cv. 'Lunoble') were grown on plots at three locations during two years and ensiled in small laboratory silos to evaluate nutrient quality and ensiling characteristics. When lupin had reached a Maturity Code of 70-71 (Mosjidis et al., 1996), approximately 4.5 kg of lupin plants were cut from four replicates at each site, dried for 8-12 h and chopped through a garden shredder/chipper. Silages were sampled and subsequently analyzed for DM, pH, ADF, NDF and CP. Approximately 1.8 kg from each replicate were tightly packed into mini-silos (10 X 35 cm) made of polyvinylchloride drainage pipe. Silos were capped at each end with a plumber's pressure end cap and set aside at room temperature for subsequent analyses (Lin et al., 1993) for internal temperature, pH and volatile fatty acids (VFA) analyses at 4, 7, 21, 28 and 90 d post-filling. Silos material was also analyzed for DM, CP, and NDF at ensiling and at 90 d. In vitro dry matter digestibility was determined at 90 d.
Complete data is available only for the 1994 year (Table 3) and plants were not available at one site (central Alabama) in 1995. Internal silo temperatures varied little and were essentially the same as room temperatures (24-26° C) from 4 d through 90 d. The CP values (12.8-15.8%) are lower than, but ADF and NDF values are similar to, those of Murphy et al. (1993). The pH dropped rapidly to a desirable level within a few days and remained low through 90 d indicating satisfactory ensiling. Butyric acid values were higher than desirable, perhaps as a result of the moisture content as the one silage sample with 35.5% DM had lower butyric acid content.

Lactation studies. **Study 1.** A preliminary, short-term lupin study in 1994 compared lactation dairy cow performance when fed diets based on either lupin (cv. 'Lunoble') or corn silage. Lupin was cut from experimental plots at a Maturity Code of 75-77 (50-70% of pods at final length) and ensiled in polyethylene bags placed within 208 L metal barrels. Due to the lack of lupin silage supply, production data are limited, but results indicated that lupin silage was a viable feed source for dairy cattle. Values for cows on corn silage and lupin silage based diets, respectively, were: DMI (kg d^{-1}) 26.2, 27.9; milk yield (kg d^{-1}) 35.8, 36.4; milk fat (%) 4.17, 3.83; milk protein (%), 3.30, 3.23. Results did not differ but were confounded because lupin diets contained less silage (18.5 vs 38.7% of DM) and more corn (47.2 vs 22.1% of DM) to provide an isocaloric diet.

Study 2. Approximately 55 Mg of lupin plants (cv. 'Lunoble') were field chopped on 5/16/95 with a commercial silage chopper at a Maturity Code of 70-71 and directly ensiled into polyethylene bags (3.65 X 20 m; Ag Bag; Warrenton, OR). A similar amount of temperate corn, millet and tropical corn were ensiled in a similar manner on 5/24/95, 8/4/95 and 8/1/95, respectively. A 14 d adaptation period followed by a 77 d lactation study commenced in early January, 1996 with 10 lactating Holsteins assigned to each of four dietary treatments. The chemical composition of the silages are in Table 4. Diets (Table 5) were formulated to contain similar silage content with other ingredients varied to obtain a calculated isocaloric and isonitrogenous diet to meet NRC (1989) requirements. Cows were maintained in tie stalls within an open-sided barn from 24:00 til 07:00 and from 10:00 til 16:00 and were in an outside paddock while not in the barn. Diets were individually fed ad libitum while in tie stalls with fresh feed placed in the bunks at 08:00 and refusals weighed back the following day prior to feeding. Cows were milked twice daily at 01:00 and 13:00. Milk weights were recorded daily and alternate a.m./p.m. milk samples taken weekly for subsequent analyses. Data were analyzed using the mixed models procedure of SAS (1985).

Results obtained to date on DMI, milk yield and milk composition are in Table 6. The DMI of the diet containing lupin was less than that of the temperate corn diet, more than for the pearl millet diet and the same as for the tropical corn diet. Milk yield of cows on temperate corn diets were greater than that for cows receiving tropical corn or pearl millet diets but not different than for cows on lupin diets. Milk yield of cows receiving lupin, pearl millet and tropical corn containing diets did not differ. No difference existed in 3.5% FCM or milk composition. As indicated previously, soluble nitrogen may be of concern with many legume or grass silages. Blood urea nitrogen (BUN) and milk urea nitrogen (MUN) are considered to be an indication of protein status (Hutjens and Barmone, 1995). Cows on all diets in this study had high BUN and MUN levels by some standards with those cows on millet diets having higher BUN values than for cows on other silages. The MUN was higher on millet silages than for temperate corn but did not differ from the other silages. Additional analyses are needed before relating these to other factors. It is interesting to note that the rumen pH of cows on millet silage was lower than for cows on other silages.

Data on digestibility, body weights, rate of passage and other factors are being analyzed. However, the analyzed data indicates that lupin silage can be fed satisfactorily to lactating cows. Ensiling at an earlier maturity would increase the energy and protein content of the silage and thereby reduce the amount of other feeds to enhance the energy and protein content of the diet. Ensiling lupin earlier than the maturity used in this study could improve nutrient content but pose concerns relative ensiling due to the moisture content of the silage. Both soybean and Andrean lupin (*Lupinus mutabilis* L.) have been mixed with corn silage which improves the crude protein but decreases the energy content of the corn silage (Daniel and Romer,1988). Lupin intercropped with cereals may improve silage quality by decreasing the moisture content and possibly increasing the carbohydrate content of the silage. Various binary mixtures of lupin and cereal crops are being evaluated (R. Jannasch, Personal Communication; E. van Santen, unpublished data). van Santen (unpublished data) observed a DM increase in material as the proportion of oat (Avena sativa) to lupin increased from 0:1 to 1:3 to 1:1. The fiber content decreased indicating a relative feed value (Holland and Kezar, 1990) of 107 for pure lupin and 127 for a 1:3 mixture of oat and lupin.

SUMMARY .

Lupin seed can provide an on-farm protein/energy supplement in climates not favorable for other oilseeds. The seeds are an acceptable protein source for beef and dairy cattle but the protein value for sheep is unclear. Grinding and heat treatment normally improve seed value, at least for dairy cattle. Feed intake may be less with lupin seed than SBM containing diets when fed to dairy cows, but most studies show no milk yield reduction. Studies will need to focus on methods to diminish the depression of milk protein as many areas price milk based upon milk protein content. Whole plant lupin are a viable source of forage as silage for beef and dairy cattle and as a feasible pasture crop for sheep. The value of lupin for both pasture and silage will be influenced by maturity and ensiling methods. The use of lupin as forages need further investigation.

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Table 1. Recommend DMI, energy and crude protein (CP) content of diets for selected ruminants

	DMI kg d^{-1}	ME MJ kg^{-1}	NE_L MJ kg^{-1}	CP %
Lactating animals				
Dairy cows: milk yield				
20 kg d^{-1}	16.2	10.5	6.32	15.0
40 kg d^{-1}	22.9	11.8	7.04	17.0
Beef cow, 400 kg BW	8.5	8.8	--	10.2
Ewe (60 kg BW); twins	2.6	9.8	--	15.6
Young animals, (BW, gain)				
Dairy calf (125 kg, .75 kg d^{-1})	3.4	12.7	--	16.0
Beef steers (227 kg, 1 kg d^{-1})	5.9	10.6	--	12.0
Lambs (30 kg)	--	10.5	--	14.7

[1]Source: Beef: NRC, 1984; Sheep: NRC, 1985; Dairy: NRC, 1989. DMI = dry matter intake, ME = metabolizable energy, NE_L = net energy for lactation, CP = crude protein, BW = body weight.

Table 2. Chemical composition of lupin seed[1] and selected feeds[2] (DM basis)

Feeds	ME MJ Kg^{-1}	NE_L	CP %	EE %	NDF %	ADF %
Corn silage	11.2	6.7	8.1	3.1	51	28
Bermuda grass hay	6.2	3.9	8.0	1.4	78	43
Alfalfa hay, mid	8.9	5.5	17.0	2.6	46	35
Barley	13.8	8.1	13.5	2.1	19	7
Corn	14.0	8.2	10.0	4.3	9	3
Corn Distillers	14.2	8.3	23.0	9.8	43	17
SBM	14.3	8.1	49.0	1.5	--	10
SB Seed	15.0	8.8	42.8	18.8	--	10
Lupin seed						
Average	--	--	34.9	9.4	21	15.2
Range	--	--	30-40	7-11	17-27	10-19

[1]Source: Values from 13 reported studies. [2]Source: NRC, 1989. ME = metabolizable energy, NE_L = net energy for lactation, CP = crude protein, EE = ether extract, NDF = neutral detergent fiber, ADF = acid detergent fiber.

Table 3. Composition of lupin silages ensiled in mini-silos.

	Location			
	AL-C	AL-S	FL-NW	SEM
1994 Crop				
DM, %	20.9	23.6	18.6	
CP, % of DM	15.8	13.5	12.8	0.59
ADF, % of DM	37.6	43.2	--	0.64
NDF, % of DM	45.9	49.7	45.1	1.24
IVDMD, % of DM	65.4	66.0	64.2	0.95
pH: d 0	5.30	5.29	5.35	
pH: d 4	4.56	4.28	4.69	
pH: d 90	4.18	4.02	4.08	
Acedic acid, % DM, d 90	0.55	2.49	1.71	
Butyric acid, % DM, d 90	3.03	1.88	2.53	
Lactic acid, % DM, d 90	4.28	6.38	6.62	
1995				
DM, %	--	35.5%	17.5%	
pH, %	--	5.37	5.60	
pH, d 7	--	4.41	4.46	
pH, d 90	--	4.11	3.98	
Acetic acid, % DM	--	1.06	1.18	
Butyric acid, % DM	--	0.45	1.39	
Lactic acid, % DM	--	4.17	6.07	

AL-C = Central Alabama; AL-S = South Alabama; FL-NW = Northwest Florida. DM = dry matter, CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, IVDMD = in vitro dry matter digestibility.

Table 4. Chemical composition of silages used in lactation diets

	Corn			
	Temp.	Trop.	Millet	Lupin
DM, %	39.1	30.0	30.4	26.0
CP, % DM	7.6	8.8	11.9	13.7
Sol N, % Total	44.1	41.9	57.4	55.2
Lactic Acid, %	3.29	5.71	2.67	4.26
Acetic Acid, %	0.51	0.75	0.42	1.47
NDF, %	59.0	57.0	50.0	50.2
ADF, %	23.0	29.0	28.0	43.0
NE_L, MJ^{-kg}	5.44	5.56	5.98	4.94
ME, MJ^{-kg}	8.91	9.12	9.87	7.99
NSC, %	25.8	26.7	30.6	28.6
Lupanine, % DM	--	--	--	0.15

Temp. = temperature, Trop. = tropical, DM = dry matter, CP = crude protein, Sol N = soluble nitrogen, NDF = neutral detergent fiber, ADF = acid detergent fiber, NE_L = net energy for lactation, ME = metabolizable energy, MJ = megajoule, NSC = non structural carbohydrate.

Table 5. Ingredient and chemical content of silage based diets for lactating cows.

	Treatments			
	Temp. Corn	Trop. Corn	Millet	Lupin
Ingredients, % DM				
Silage	40.0	40.0	42.4	40
Soyhulls	26.1	25.6	26.0	8.7
WCS	14.2	14.2	14.2	14.2
SBM (48%)	11.2	10.5	7.5	6.5
CSH	25.0	5.0	5.0	5.0
Ground corn	0	0	0	22.0
Megalac®	1.5	1.8	1.2	1.8
Mineral mix	2.0	3.0	3.8	1.8
Chemical composition				
DM, %	57.5	55.8	51.9	48.8
CP, %DM	15.5	15.5	15.6	15.6
ADF, % DM	31.2	34.6	34.5	29.0
NDF, % DM	44.2	48.9	47.5	37.2
NE_L, MJ kg^{-1}	7.15	6.86	6.86	6.95
ME, MJ kg^{-1}	12.11	11.56	11.56	11.65

DM = dry matter; WCS = whole cottonseed, SBM = soybean meal, CSH = cottonseed hulls, Megalac® = commercial dry fat source, CP = crude protein, ADF = acid detergent fiber, NDF = neutral detergent fiber, NE_L = net energy for lactation, ME = metabolizable energy, MJ = megajoule.

Table 6. Least squares means for feed intake, production and physiological values of cows on silage based diets.

	Treatments				
	Temp. C	Trop. C.	Millet	Lupin	SE
DMI, Kg d^{-1}	23.5^{a}	19.8^{bc}	17.2^{a}	19.6^{bc}	1.09
Milk, Kg d^{-1}	30.0^{a}	26.8^{b}	26.3^{b}	28.5^{ab}	1.08
3.5 FCM, Kg d^{-1}	30.7	27.0	27.3	29.3	1.81
M. Fat, %	3.7	3.8	3.7	3.6	0.12
M. Protein, %	3.1	3.0	2.8	2.9	0.06
BUN, mg dl^{-1}	17.9^{b}	18.6^{b}	21.1^{a}	18.4^{b}	0.33
MUN, mg dl^{-1}	16.7^{a}	18.2^{ab}	19.0^{b}	18.2^{ab}	0.27

^{abc}Means with unlike superscripts within a row differ (P<.05). Temp. C. = temperature corn, Trop. C. = tropical corn, DMI = dry matter intake, BUN = blood urea nitrogen, MUN = milk urea nitrogen.