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Original

Substitution of Soybean Paste with Lupinus mutabilis Grain in Balanced Feed for Dairy Cows

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ABSTRACT

Background: In recent years, milk production has increased by 2 to 3% per cow per year, leading to higher nutritional requirements. Various feeding alternatives for bovine species have been studied to meet these demands. **Aim.** To evaluate the effect of replacing soybean paste with *Lupinus mutabilis* (lupin) grain in balanced feed for dairy cows. **Materials and methods:** The study was conducted at the "Irquis" experimental farm of the University of Cuenca, located in the province of Azuay. Six pairs of unregistered Holstein cows, each pair with equal parity, were selected and divided into two groups, with one cow from each pair in each group. A Switchback design was used for two treatments: balanced feed with lupin and balanced feed with soybean. The experiment consisted of three periods with breaks between them, each period including three days of initial adaptation followed by seven days of measurements, with individual milk production weighed. On the last day of each period, 400 ml milk samples were taken from the twelve cows and transported to the Lactology Laboratory of the University of Cuenca for analysis of fat percentage, protein, lactose, total solids, fat solids, and density. **Results:** The results showed no significant differences ($P > 0.05$) in milk production, milk quality, fat percentage, total solids, density, or pH between the two treatments. However, the soybean-based feed was superior ($P < 0.05$) in protein, lactose, and non-fat solids content. **Conclusions:** The use of lupin in dairy cow feed could effectively replace soybean paste as a source of protein and ether extract for the production of balanced feed. Due to its nutritional composition, lupin can influence milk production at levels similar to soybean paste, but further experiments are required in this area.

Keywords: cattle, lupin, concentrated feed, milk production (Source: AGROVOC)

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INTRODUCTION

The genus *Lupinus* originates from the Andean region of Peru, Bolivia, and Ecuador, where the majority of the genetic variability of the species *Lupinus* is found. In these three countries, 83 species have been identified, with the most common being *L. mutabilis, L. luteus, L. angustifolius* and *L. albus*. Chiguachi (2017). Lupin was widely cultivated in the Andean region of Ecuador, but its cultivation has drastically decreased because farmers find it difficult to compete with imported legumes that are more commercially viable and generate higher income. As a result, the country has turned to importing cereal grains for the production of balanced feed to meet national market demands, as local crops are insufficient (Peralta, 2016).

Due to the lack of supplements, the average daily milk production from dairy cows is low, higher than in the province of Azuay (7.56 kg) but lower than in the province of Pichincha (11.27 kg). Other reports from ESPAC (2021) indicate that this is the most common level of daily milk yield in most dairy farms in Ecuador and the Pacific region of South America.

In 2022, APROBAL (Association of Balanced Feed Producers) reported that the country imported 1,490,000 metric tons of soybean meal. The Ecuadorian agricultural sector offers only 20,000 hectares of soybean cultivation, while 750,000 hectares are needed to meet the total demand. On the other hand, Ecuador produces approximately 40,000 metric tons of soybeans, of which only a portion is used for balanced feed production, and the rest is used for other by-products such as soybean oil. APROBAL recommends exploring alternatives to soybean that offer similar nutritional content.

Lupin seeds, according to Lucas *et al*. (2015), are a good alternative as a protein source in dairy cow feed. Froidmont and Bartiaux-Thill (2004) replaced soybean with lupin and pea grains and found that milk production increased, and milk fat content improved when lupin replaced 75% of the soybean. Therefore, the authors concluded that lupin seeds can efficiently replace soybean in high-production dairy cow feed. Emile *et al*. (1991) used *Lupinus albus* to replace soybean in dairy cows in three trials and concluded that this grain can be used to produce concentrates and replace soybean. Currently, there are no reports in Ecuador of lupin being used as an alternative to other protein sources, particularly soybean, which dominates balanced feed for milk production.

Accordingly, the purpose of this study was to evaluate the effect of replacing soybean paste with lupin grain (*Lupinus mutabilis*) in balanced feed for dairy cows.

MATERIALS AND METHODS

Location

The study was conducted at the "Irquis" experimental farm of the University of Cuenca, Ecuador, located at 2,663 meters above sea level. The farm covers approximately 507.8 hectares, with an average temperature of 8°C.

Experimental Methodology

Two treatments were prepared: T1: Balanced feed with lupin grain and T2: Balanced feed with soybean paste (control). The amount of feed administered was based on the milk production of each animal, which was expected to be around 11 kg per day. The feed formulation at the Irquis experimental farm included wheat bran, ground corn, oat bran, molasses, soybean paste, and mineral salt. In the experimental treatment, soybean was replaced with lupin according to the nutritional requirements of dairy cows. When the cows finished milking, those that were to consume T1 or T2 were identified according to the period they were in. With the help of the ribbons, they entered the feeding stall one by one. As they entered, the feed was placed in front of them, ensuring that each cow consumed its respective balanced feed. The selected cows graze continuously in a rotational system, taking into account that there are times when this activity is interrupted when the animals are moved to the milking parlor twice a day.

Six pairs of unregistered Holstein cows were selected, each pair with the same number of calvings, ranging from two to four, and with up to three months of lactation. They were divided into two groups, with one cow from each pair assigned to each group. A Switchback (double reversal) design proposed by Lucas (1956) and used by Obispo *et al*. (2004) was employed, consisting of three periods with breaks between them. Each period included three days of adaptation followed by seven days of measurements, with individual weighing of the milk produced.

On the last day of each period, 400 ml milk samples were taken from the twelve cows and transported to the Lactology Laboratory of the University of Cuenca for analysis of milk quality, fat percentage, protein, total solids, non-fat solids, and density. The cows were selected based on body condition (scored on a scale of 1 to 5, with values around 3 and 4).

Bromatological Analysis of Lupin

Table 1 shows the results of the bromatological analysis of the lupin grain used in the study (described in the methodology).

Table 1. Bromatological composition of *Lupinus mutabilis* sweet grain

Parameter	Unit	Result
Ashes	%	1.176
Fiber	%	19.47
Ethereal extract	%	15.696
Moisture	%	0.584
Protein	%	44.926

Based on the nutritional requirements of the cows at the Irquis farm, a total of 2.75 kg of balanced feed per cow per day was administered (lupin Table 2 and soy Table 3), distributed in two daily rations after each milking (morning and evening).

Table 2. Formulation of a lupin-based diet for dairy cattle at Irquis Farm

INGREDIENTS	Inclusion % Dry base	ME		CP		CF	
		Kcal/Kg DM		DB%		DB%	
		Cont.	Calc.	Cont.	Calc.	Cont.	Calc.
Corn meal	13.900%	3315.52	460.86	9.20%	1.28%	2.50%	0.35%
Sugarcane molasses	2.200%	2795.85	61.51	4.08%	0.09%	3.40%	0.07%
Wheat bran	46.700%	2905.61	1356.92	14.61%	6.82%	18.30%	8.55%
Lupin	9.000%	1700.58	153.05	45%	4.86%	19.47%	1.20%
Oat bran	28.200%	2490.00	702.18	4.01%	1.13%	32.15%	9.07%
Calculated Σ	**100.00%**	**2734.52**		**14.18%**		**19.23%**	
Requirement	**100.00%**	**2500.00**		**15.00%**		**20.00%**	

Table 3. Formulation of a soy-based diet for dairy cattle at Irquis Farm

INGREDIENTS	% Inclusion Dry base	ME		CP		CF	
		Kcal/Kg DM		DB%		DB%	
		CONT.	CALC.	CONT.	CALC.	CONT.	CALC.
Corn meal	13.900%	3315.52	460.86	9.20%	1.28%	2.50%	0.35%
Soy paste	9.000%	2694.03	242.46	52.81%	4.75%	3.70%	0.33%
Sugarcane molasses	2.200%	2795.85	61.51	4.08%	0.09%	3.40%	0.07%
Wheat bran	46.700%	2905.61	1356.92	14.61%	6.82%	18.30%	8.55%
Oat bran	28.200%	2490.00	702.18	4.01%	1.13%	32.15%	9.07%
Calculated Σ	**100.00%**	**2823.93**		**14.07%**		**18.37%**	
Requirement	**100.00%**	**2500.00**		**15.00%**		**20.00%**	

RESULTS AND DISCUSSION

The results of milk production over the last three days of each period showed no significant difference between the two treatments (see Table 4). This aligns with the expected similar outcome when formulating the feed to ensure that both meet the nutritional requirements of the cows at a production level of 11 kg of milk per day. By verifying that the lupin-based feed achieves a daily milk yield equivalent to that of the soybean-based feed, the basic information is obtained to establish the use of lupin as an alternative for dairy cattle feed on medium-production farms in the Ecuadorian highlands.

Table 4. Comparison of average milk production over the last three days of each period

Component	Treatments		
	T1 (Lupin)	T2 (Soybean)	
Production	9.18 ± 1.362	8.45 ± 1.167	P > 0.05

P values (P > 0.05) are not significantly different.

Menkowski *et al.* (2019) reported that milk production exceeding 20 kilograms per day was achieved when comparing treatments with soybean to treatments with different mixtures of faba beans and lupin in diets for Holstein cows. However, forages accounted for 60% and concentrated mixtures for 40% of the diet, the latter being significantly higher than what was used in this study and thus influencing higher daily production. Nevertheless, in those experiments, soybean did not significantly differ from lupin.

Regardless of the superiority of soybeans in terms of protein percentage and the more favorable ether extract content of lupins, as well as other nutritional components, as reported by Sánchez and Díaz (2019), both feeds are capable of adequately nourishing cows and resulting in similar production levels. In this study, with a much lower proportion of concentrates in the diet, soybeans did not outperform lupins when the inclusion percentages of each feed are similar.

These results differ from the study by Froidmont and Bartiaux-Thill (2004), who mentioned that milk production increased when replacing soybean meal with lupin grain. This discrepancy could be due to the fact that they used a different variety of lupin (*Lupinus albus*) compared to the one used in this study (*Lupinus mutabilis*), which has a higher protein content.

Emile *et al*. (1991) determined that lupin efficiently replaces soybean meal. This replacement was evaluated in different rations with varying substitution percentages, resulting in equal or greater milk production compared to the use of soybean meal, depending on the percentage included in the ration.

In a study on the bromatology of debittered lupin, a protein percentage of 54.05% was obtained (Allauca, 2005). In this study, the protein value, which is one of the most important parameters outlined in the objectives, was 44.93%. Likewise, a notable difference is evident in the fat content of lupin, as the aforementioned author obtained a result of 21.22%, while in the present research, the grain had 5.53 percentage units less.

Milk quality

To evaluate the quality of the milk, the mean of each parameter was calculated, taking into account the treatment under which the milk samples were assessed. In this way, differences were observed among the treatments, except for FAT and TOTAL SOLID %, as shown in Table 5.

Table 5. Milk quality

VARIABLE	T1-lupin-based balanced feed		T2-soy-based balanced feed		Significance
	MEAN	±SE	MEAN	±SE	
FAT %	3.78	1.329	3.62	1.153	P > 0.05
PROTEIN %	3,24a	0.015	3,30b	0.124	P < 0.05
LACTOSE %	4,94a	0.025	4,99b	0.157	P < 0.05
NON-FAT SOLIDS.	8,99a	0.084	9,13b	0.290	P < 0.05
TOTAL SOLIDS	12.61	0.428	12.72	0.654	P > 0.05
DENSITY	1030,67a	4,350a	1031,17b	2,086b	P < 0.05

P values (P > 0.05) are not significantly different.

Reyes (2010) mentions that the percentage of fat in milk can vary among cows of the same breed depending on the feed they consume, establishing a relationship where a higher fiber intake in the diet leads to a higher fat percentage. Their results align with this study, as the cows that consumed the feed containing lupin grain showed no differences in fat percentage or total solids compared to those that received soybean, despite the higher ether extract content in lupin, as noted by May *et al*. (1993) agreed with these results and also found no differences between supplementation with soybean and various levels of substitution with lupin. Significant differences favoring soybeans in protein and fat concentration, but not in lactose, have been reported by Wendowski *et al*. (2019). These same authors have suggested that the results are generally contradictory, and it should be considered that after some studies in the 1990s, reports decreased partly due to the processing costs of lupin grains. More comprehensive and diverse experiments are needed in the Andean highlands to reach consistent conclusions.

CONCLUSION

The use of lupin in dairy cow feed could effectively replace soybean paste as a source of protein and ether extract for the production of balanced feed. Due to its nutritional composition, lupin can influence milk production at levels similar to soybean paste. However, more experiments are needed in this area.

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AUTHOR CONTRIBUTION STATEMENT

Research conception and design: MKSC, MMMP, GEGV, RVGV, CSTI; data analysis and interpretation: MKSC, MMMP, GEGV, RVGV, CSTI; redaction of the manuscript: MKSC, MMMP, GEGV, RVGV, CSTI.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.