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Break-even analysis of crude protein content in dairy goat feed mixture

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Abstract

The increasing global demand for goat's milk is a good opportunity for producers to increase their production and profits. In addition to improving the genetic potential of goats and optimising feeding strategies to increase production, cost-effective measures for goat milk production must also be considered. To achieve these goals, it is important to understand the role of crude protein in goat feeding. The aim of this study was to determine the optimum and economically justifiable crude protein content in the feed mixture as a supplementary feed for goats in intensive milk production. The study was carried out over two production years within a herd of 70 Alpine goats. In the first year (control year), goats were fed a feed mixture containing 12 % crude protein. In the second year, the animals were randomly assigned to three experimental groups, each receiving a feed mixture with a different crude protein content (14 %, 16 %, or 18 %). Based on the average lactation yields and the ratio between revenues and costs in all three feeding groups, the coverage of the average costs of the feed mixture by the price of the milk revenues was evaluated. The results showed that feeding goats with a mixture containing 18 % crude protein significantly improved economic profitability and achieved the highest gross margin, both compared to the baseline year and compared to the groups fed lower protein levels. These results are crucial for producers engaged in intensive goat milk production, as they emphasise the need to adapt the goats' diet to achieve optimal and economically sustainable results. By strategically increasing crude protein levels, farmers can improve both the profitability and efficiency of their operations.

Keywords: goat milk; feed mixture; gross margin; crude protein

Introduction

The profitability of goat's milk production is playing an increasingly important role in the dairy industry and offers both small and commercial farmers the opportunity to improve their income. A key factor influencing this profitability, especially in intensive production systems, is the crude protein content of the goat feed, which not only affects the quantity and quality of the milk produced, but also has a significant impact on production costs (Huhtanen and Hristov, 2009; Goetsch et al., 2011). Studies show that feed costs account for around 70 % of direct costs in goat milk production, with protein being the most expensive component of the diet (Fox et al., 1992; Santos et al., 2017). According to Očić et al. (2023) own fodder, or own land for its production, is the main limiting factor for intensive milk production due to the underdeveloped fodder market in Croatia. In order to optimise feeding strategies on dairy goat farms, it is important to consider herd size and farming intensity. These factors help to meet the nutritional needs of goats and ensure their health and good reproductive performance. However, achieving these goals is associated with various economic challenges. This is in line with the findings of Navarrete-Molina et al. (2024), who emphasise the increasing importance of dairy goat production for increasing the income of smallholder farmers, especially in marginal and arid regions where goats are an important source of livelihood. The relatively low milk yield and selling price of milk, with relatively high operating costs, resulted in lower net production margins and affects the competitiveness of small Croatian farms (Očić et al., 2023). Increasing the protein content in dairy goat diets can increase milk production, but also harbours the risk of metabolic and health problems, such as nitrogen losses due to ammonia in the case of excess protein or serious health problems in the case of insufficient protein intake (Zhao et al., 2023). In addition, the quality of the milk produced - in particular its fat and protein content - plays a decisive role in the dairy industry, as there is often an inverse relationship between milk quantity and quality. Therefore, a balanced ration structure that is orientated towards the actual needs of the animals is crucial for cost savings, high yields and the desired milk quality. This approach also helps to fully utilise the genetic potential of goats (Lapierre and Lobley, 2001; Luo et al., 2022; Zhao et al., 2023). Adequate nutrition is essential for the health and reproductive performance of goats, which in turn improves the profitability of their breeding programmes. Therefore, in addition to genetic selection, it would be beneficial to emphasise strategies to improve feed quality and cost efficiency to support sustainable goat breeding (Manirakiza et al. 2021).

Common sources of protein in goat diets include feedstuffs such as hay, alfalfa, barley, maize, oats and soya meal, although protein requirements vary in the different production phases, particularly during growth, gestation and lactation. To improve the growth performance and efficiency of milk production, the use of high-quality protein raw materials such as soya meal, sunflower meal and rapeseed meal is crucial. Given the limited availability of local forage crops and the current economic situation, it makes economic sense to consider the inclusion of additional forage crops. Investigating the cost efficiency of various feed mixtures is important, as it allows farmers to determine which protein sources are economically viable. A balanced feed mixture that incorporates non-local raw materials can be economically feasible if properly managed. However, farmers must also critically evaluate which protein sources to include on the basis of cost-effectiveness in order to avoid unnecessary expenses.

In intensive dairy goat farming, the higher crude protein content in the diet is often due to the higher protein content of the feed used compared to typical dairy cow feeding, which is often based on maize silage with a low protein content. In spring and summer, when goats usually reach the peak of lactation production, feeds usually contain more than 12 % crude protein in dry matter, while purchased feeds can be even richer and often contain more than 16-20 % protein (Rapetti et al., 2020). Although some farmers believe that more protein in dairy goats' feed leads to higher milk yield and quality, this often results in excessive feed costs and a negative impact on the environment, as too much nitrogen is often lost due to the imbalance between energy and protein in the meal. To achieve profitable and sustainable goat milk production, it is therefore essential to rationalise the use of protein in feed. The aim of this study is to determine the economic limits of adding crude protein to feed mixtures in intensive goat milk production, measured in terms of the quantity of milk produced and the relationship between income and costs, in order to ultimately guide farmers towards more efficient feeding methods.

Materials i methods

The study was carried out in a herd of 72 Alpine goats in two consecutive production years. In the first year (control year), the goats were randomly divided into 3 groups of 24 randomly selected animals without visible signs of mastitis, which received a feed mixture with 12 % crude protein, while in the second (experimental) year they received feed mixtures with a different crude protein contents. The first group of goats received a feed mixture with an optimal crude protein content (16 %) in accordance with Nutrient requirements of goats (NRC, 2007). The other two groups of goats were fed a diet with a crude protein content in the feed mixture that was 2 % higher (18 % CP) and 2 % lower (14 % CP) than that of the first group. All goat rations were isoenergetic, i.e. the energy value of the ration did not change and was the same for all groups of goats. The study lasted from the 35th day of lactation until dry-off (270-280th day of lactation).

The basic voluminous ration of the goats consisted of a clover-grass hay and was not changed during the study. The goats were fed a feed mixture as a supplement to the voluminous part of the meal, which they received in the milking parlour during morning and evening milking at a rate of 0.5 kg/meal, while the voluminous part of the meal was given ad libitum. The raw material composition of all feed

mixtures was as follows: 30 % maize, 15 % wheat, 10 % barley, 6 % oats and 39 % super concentrate mixture with varying proportions of crude protein.

Milk analysis

The milk production of the goats was monitored using the AT method (ICAR, 2016) by manual milking with an interval of 12 hours between milkings. The average period between two consecutive controls was 30 days. Milk samples were taken once a month over 7 and 8 controls (depending on the duration of lactation), i.e. until the amount of milk per milking was less than 200 ml.

Hygiene measures were observed throughout lactation: washing and disinfecting the udders and milking the first milk flows separately from the rest. On the control day, milk samples were taken from each goat during the morning or evening milking to analyse the basic chemical composition of the milk. A milk sample of 200 ml was taken from each goat, which was sufficient to carry out all the planned analyses. Total milk production was calculated using data from the monthly milk yield controls (ICAR, 2016) and refers only to the milking period, as the kids were with the goats and suckling. The date of the start of milking was used as the start date for calculating production. The quantity of milk produced was calculated using the Fleischmann formula (HSC, 2004):

$$KMI = I_0 \times KM_1 + I_1 \times (KM_1 + KM_2)/2 + I_2 \times (KM_2 + KM_3)/2 + I_{n-1} \times (KM_{n-1} + KM_n)/2 + I_n KM_n$$

where is:

- I_0 - Interval from the start of milking (from the date of last weaning, if the kid has only sucked colostrum) to the 1st control
- KM_1, KM_2,...KM_n - amount of milk milked in 24 hours in millilitres on the control day
- I_1, I_2, ...I_n - Interval between two follow-up controls
- I_n - Interval between the last control and drying off

Feed analysis

The content of dry matter, ash, crude protein (N x 6.25), crude fibre and other ingredients in the feed samples was determined in the laboratory for feed analysis at the University of Zagreb, Faculty of Agriculture. Analyses of the chemical composition of the meal were carried out before the start and at the end of the study.

The following parameters were determined in the samples of feed mixtures and hay:

- the moisture content by drying according to HRN ISO 6496:2001;
- the crude protein content using the water vapour distillation method on the Kjeltec 8200 instrument, according to HRN EN ISO 5983:2010;
- the percentage of fat using a modified extraction method on the instrument ANKOM XT 15 according to HRN ISO 6492:2001;
- the percentage of crude fiber using the method with intermediate filtration with the FOSS Fiber Cap instrument according to HRN EN ISO 6865:2001;
- the percentage of ash according to HRN ISO 5984:2001.

Statistical analyses

To determine the limit of economic profitability of adding crude protein to the feed mixture, the cross margin was used to monitor the relationship between income (milk prices) and variable costs (feed costs) for all three groups of goats studied. These results were compared with the control production year. The production system (animal husbandry, milking methods and hygiene, type of feed, ratio of bulky and concentrated feed in the ration) was identical for all goat groups studied, with the exception of the crude protein content in the super concentrate mixture (21 %, 27 % and 35 %). The financial analysis was based on the cost of the individual ration components, the values consumed by the animals, the efficiency of the feed consumed and the milk production in each experimental group. The cost of each meal component was calculated based on feeding standards and average prices for the two years observed and for the composition of one kilogramme of feed mixture for all three experimental groups. The values are based on the percentage of the recipe (Table 2) and the market price of the super concentrate mixture. The value of a litre of goat's milk is calculated as the average purchase price for milk with a mark-up (EUR/litre).

Results and discussion

In the first year of the trial, the average daily milk yield was 2.92 kg/goat. This amount was 0.01 kg, 0.41 kg and 1.03 kg lower than the average daily milk yield per goat in the second (experimental) year (Table 1). Increasing the crude protein content of the goats' ration by 2 %, 4 % and 6 % compared to the control year led to an increase in daily milk yield of 0.34 %, 14.04 % and 35.3 % respectively. As ALKaisy et al. (2023) reported, one of the main benefits of using high-protein feeds in goat diets is the significant increase in milk production. Zhao et al. (2023) found that higher protein levels in the diet of lactating ewes (13.93 %) significantly increased milk yield compared to lower protein levels (8.38 % and 10.42 %). Their study showed that the highest protein content (S-h) led to higher milk yield without significantly affecting milk protein content. However, this increase in milk yield is often accompanied by a decrease in milk fat and protein content, which is partially confirmed by this study. As the crude protein content of the goat feed increased, the daily milk yield increased, but the milk fat content decreased, while the protein content remained relatively stable. This phenomenon can be attributed to the possible negative effects of a high-protein diet on rumen health. In particular, a high-protein diet can lead to acidification of the rumen contents, resulting in lower digestibility of fibre-rich feed and reduced synthesis of microbial proteins. Consequently, this can lead to a lower

protein content in the milk, as Babnik et al. (2004) explain. According to Bendelja Ljoljić et al. (2023), higher dietary protein levels in dairy goats lead to markedly higher milk urea concentrations, which in turn result in excessive nitrogen excretion from the organism. In addition, feedstuffs containing easily digestible proteins, such as green fodder, wheat and barley, generally do not provide a high protein content in milk. In contrast, Feldhofer and Vašarević (1998) suggest that producers can effectively increase the protein content in milk by feeding cows a combination of easily degradable proteins and more stable proteins such as maize silage, sunflower meal, rapeseed, dried hay and soya hulls. This highlights the importance of balancing protein sources in goat diets to maximise milk production while maintaining the desired composition of milk. Interestingly, the socio-demographic characteristics of farmers, such as their farming experience, can also influence management practises that affect milk production outcomes. For example, in a study conducted in Greece, farmer experience was found to be negatively related to the use of health management practises, which in turn affected milk production and quality on small ruminant dairy farms. Farmers with more experience tended to neglect certain management practises that are crucial for maintaining optimal milk quality, such as the use of scleroderma vaccination and ultrasound examinations for pregnancy diagnosis (Lianou and Fthenakis, 2021). These results suggest that improving the management skills of experienced farmers through targeted training could improve overall production parameters, including milk yield and composition.

Table 2 presents the daily cost of the feed mixture for goats based on different compositions and crude protein percentages over two years.

In the first year, the feed mixture consisted of maize (40 %), oats (10 %), barley (20 %) and wheat (30 %) with a crude protein content of 12 %. The costs for this feed mixture in the first year were calculated for each component. In the second year, variations in the composition of the feed mixture were introduced with different crude protein contents of 14 %, 16 % and 18 %. The proportions of maize, oats, barley and wheat were adjusted accordingly. In addition, concentrated feed mixture (CFM) was added in the second year in a proportion of 39 % for all animal groups. The prices per kilogramme of the feed components were given to calculate the total daily cost of the feed mixture for each scenario in the second year. The increase in crude protein content and the addition of the CFM resulted in a higher cost for the feed mixture in the second year compared to the control year. This allows cost comparisons based on different feed compositions and protein levels so that leather farmers can make informed decisions about feed management and cost optimisation for their animals.

Table 3 shows the coverage of the average cost of the feed mixture by the milk price together with the gross margin values for different scenarios. The table compares the milk price, the daily milk production, the cost of the feed mixture, the daily amount of feed mixture and the gross margin for the control year and three scenarios in the second year with different crude protein (CP) contents in the feed mixture.

Table 1. *Milk production parameters during two years (mean values)*

	1st year	2nd year		
Parameter	12 % CP	14 % CP	16 % CP	18 % CP
Milk yield, kg	727.08	744.22	855.81	1023
Lactation, days	249	254	257	259
Daily milk yield (kg)	2.92	2.93	3.33	3.95
% milk fat	3.16	3.26	3.16	3.00
% protein	2.87	2.86	2.85	2.76

CP - crude protein

Table 2. *The daily cost of the feed mixture*

Feed mixture composition		1st year 12 % CP	Feed mixture composition	2nd year		
				14 % CP	16 % CP	18 % CP
Corn	40%	0.072	30%	0.0418	0.0418	0.0418
Oats	10%	0.014	6%	0.0084	0.0084	0.0084
Barley	20%	0.0348	10%	0.0144	0.0144	0.0144
Wheat	30%	0.0524	15%	0.0251	0.0251	0.0251
CFM	-	-	39%	0.1267	0.1432	0.1872
Price (EUR/kg)		0.173		0.216	0.233	0.277

CP - crude protein; CFM - concentrate feed mixture

Table 3. *Coverage of the average cost of feed mixture by the price of milk*

Year, CP	Milk price EUR/kg	Daily milk yield (kg)	Feed mixture cost EUR/kg	Feed mixture consumption/day (kg)	Gross margin EUR
1st, 12 %	0.68	2.92	0.173	1.0	1.81
2nd, 14 %	0.70	2.93	0.216	1.0	1.84
2nd, 16 %		3.33	0.233	1.0	2.10
2nd, 18 %		3.95	0.277	1.0	2.49

CP - crude protein

As the crude protein (CP) content in the feed mixture increases from 14 % to 18 %, daily milk yield correspondingly rises. However, the increase in milk production is associated with higher costs, as the costs for the feed mixture also increase with the higher CP content. The gross margin values show the profitability of each treatment, with a gross margin of EUR 1.81 in the control year and gross margins between EUR 1.84 and EUR 2.49 in the second year scenarios. The results show that feeding a feed mixture with a CP content of 18 % makes the largest contribution to covering the variable costs of feeding, resulting in the highest gross margin compared to the control year and the other scenarios with lower CP contents.

Overall, the results suggest that increasing the CP content in the feed mixture can lead to higher milk production and potentially higher profitability as long as the additional cost of the feed mixture is offset by the increase in milk production and gross margin. However, a direct comparison of the optimal CP level of 18 % with other studies should be made with caution. Several factors influence the ideal protein content for a particular herd, including breed, stage of lactation, body condition and general feed composition. For example, Lu (1993) studied isoenergetic diets with varying fat content for Alpine goats in early lactation. Although this study is not directly comparable due to breed and nutritional differences, it shows how important it is to consider the interaction of the different nutritional components and not just the protein alone. Huhtanen and Hristov (2009) found that crude protein (CP) concentration in the diet is a significant predictor of milk protein yield (MPY) in dairy cows. They concluded that while higher CP intake can increase MPY, nitrogen (N) utilisation efficiency decreases with higher CP levels. Milk nitrogen efficiency (MNE), defined as the efficiency of converting dietary nitrogen into milk protein, was also negatively affected by higher CP intake. This means that although cows produce more milk at higher protein levels, they may not do so efficiently, resulting in higher nitrogen excretion. Interestingly, the study indicates that the degradability of CP in the rumen has no significant effect on MPY or MNE, suggesting that the quality of the protein (especially its degradability) may not be as critical as the total amount of CP ingested.

Furthermore, the generalisation of optimal CP values for different production systems and economic contexts can be misleading. The availability and cost of protein sources vary considerably, as do milk prices. A study conducted in Jordan (Aloueedat et al., 2019) investigated how conventional feeds can be replaced with alternative options such as carob pods and olive cake to address feed shortages and cost concerns. This emphasises the need for context-specific feeding strategies that take into account the availability of local resources and economic factors.

Although research focusing specifically on optimising protein intake in intensive housing systems is sparse and limited, research on dairy cows housed in similar closed systems shows some preliminary results. It is important to note that direct comparisons between different animal species (cows, goats) should be made with caution as they take into account differences in physiology and production goals. For example, research on dairy cows has consistently shown that optimising the protein content of the diet is key to maximising milk production and feed efficiency. Studies have shown that meeting the cow's specific requirements for amino acids, rather than just providing a high level of crude protein, can both improve nitrogen utilisation and reduce nitrogen excretion. This targeted approach ensures that cows utilise dietary protein efficiently for milk production rather than losing it in faeces. Based on these findings, future research on goat milk production should confirm whether these results also apply to goats in intensive systems. To achieve this, care must be taken to ensure that the specific amino acid requirements of the goat are met at the different production phases, it must be ahead of the crude protein requirement. In addition, monitoring the nitrogen content in the manure can provide valuable insights into how efficiently the goats utilise the crude protein and help to identify opportunities to adjust feeding strategies.

Conclusion

In this study, it was found that a feed mixture with 18 % crude protein (CP) significantly improved the economic profitability of goat milk production and achieved the highest gross margin among the tested feed types, suggesting that the use of this mixture could be a viable strategy to increase profitability in the study. However, looking at CP alone may overlook the critical role of amino acid balance and overall nutrient composition, which have a more direct impact on milk yield and animal health. In addition, the economic analysis did not capture costs or benefits in terms of health, reproduction and long-term sustainability that could influence profitability in practise. The potential effects of higher protein levels on health, reproductive performance and milk quality need to be carefully and specifically analysed.

To develop robust, generalisable recommendations, future research should conduct longitudinal studies across different goat breeds and production systems, evaluate multiple protein sources and their digestibility, and consider amino acid profiles. Incorporating environmental sustainability metrics into economic analyses will shed light on the broader impacts of feeding strategies. Ultimately, the goal is to refine protein recommendations tailored to specific breeds, production contexts and economic conditions while evaluating long-term health, reproductive outcomes and product quality to promote truly sustainable and profitable dairy goat production.

Analiza rentabilnosti sadržaja sirovih proteina u krmnoj smjesi za mliječne koze

Sažetak

Rastuća globalna potražnja za kozjim mlijekom dobra je prilika proizvođačima za povećanje proizvodnje i zarade. Osim poboljšanja genetskog potencijala koza i optimizacije hranidbenih strategija u cilju povećanja proizvodnje, potrebno je razmotriti i troškovno učinkovite mjere za proizvodnju kozjeg mlijeka. Za postizanje ovih ciljeva važno je razumjeti ulogu sirovih bjelančevina u hranidbi koza. Cilj ovog rada bio je utvrditi optimalan i ekonomski opravdan sadržaj sirovih bjelančevina u krmnoj smjesi kao dopunskoj hrani za koze u intenzivnoj proizvodnji mlijeka. Istraživanje je provedeno tijekom dvije proizvodne godine unutar stada od 70 alpina koza. U prvoj (kontrolnoj) godini koze su hranjene krmnom smjesom koja je sadržavala 12 % sirovih proteina. U drugoj godini koze su nasumično podijeljene u tri hranidbene skupine i hranjene smjesama s različitim sadržajem sirovih bjelančevina (14 %, 16 %, 18 %). Na temelju prosječnih laktacijskih proizvodnji i odnosa prihoda i troškova u sve tri hranidbene skupine procijenjena je pokrivenost prosječnih troškova krmne smjese cijenom prodanoga mlijeka. Rezultati ukazuju da je hranidba koza smjesom s 18 % sirovih proteina značajno poboljšala ekonomsku isplativost i postigla najveću bruto maržu, kako u usporedbi s baznom godinom, tako i u usporedbi sa skupinama hranjenim smjesom s nižim sadržajem proteina. Ovi rezultati ključni su za proizvođače koji se bave intenzivnom proizvodnjom kozjeg mlijeka jer naglašavaju potrebu prilagodbe prehrane koza za postizanje optimalnih i ekonomski održivih rezultata. Strateškim povećanjem razine sirovih proteina, farmeri mogu poboljšati i profitabilnost i učinkovitost svojeg poslovanja.

Ključne riječi: kozje mlijeko; krmna smjesa; bruto marža; sirovi proteini

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