Dairy goats fed sunflower hay intercropped with chickpea in small-scale systems. Part I: Animal performance

Cabras lecheras alimentadas con heno de girasol intercalado con garbanzo en sistemas de pequeña escala. Parte I: Desempeño animal

Cabras leiteiras alimentadas com feno de girassol consorciado com grão de bico em sistemas de pequena escala. Parte I: Desempenho dos animais

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Abstract

Background: Small-scale livestock systems provide quality food for a growing demand of animal protein worldwide. Although these systems help to improve rural living standards and reduce the environmental footprint new feeding strategies should be tested to improve animal productivity. Sunflower -which is native to México- and chickpea -also common in the study area- may be used as feed alternatives for dairy goats. **Objective:** To evaluate the effect of substituting corn straw with sunflower-chickpea hay on yield and nutrient composition of goat milk. **Methods:** In this participatory study, a total of 28 multiparous Saanen dairy goats were randomly assigned to two treatments (14 goats each) during a 30-day experiment in a small farm. Two weeks prior to the experiment all goats received an adaptation diet. One treatment (MZST) received a conventional diet of lucerne hay (200 g/goat/day) and concentrate (400 g/goat/day), plus 600 g/goat/day (50% of the ration) of corn straw. The second treatment (SFCPT) contained the same lucerne and concentrate content with 600 g/goat/day of sunflower-chickpea hay. Milk yield and composition, and live weight and body condition of the goats were recorded for each treatment. **Results:** SFCPT significantly increased milk yield, protein, and solids content, but no difference was observed in milk fat. **Conclusion:** Dietary supplementation of goats with sunflower and chickpea hay increases milk production, protein, and total solids content compared with corn hay.

Keywords: *alternative forages; caprine; chemical composition; chickpea; feed; goats; hay; legumes; Mexico; milk; sunflower.*

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Resumen

Antecedentes: Los sistemas de producción animal en pequeña escala proveen alimentos de calidad para una demanda mundial creciente de proteina animal. Aunque estos sistemas ayudan a mejorar la calidad de vida rural y reducen la huella ambiental, se deben buscar nuevas estrategias de alimentación para incrementar la productividad animal. El girasol -originario de México- y el garbanzo -común en la zona de estudio- pueden usarse como alternativa para la alimentación de cabras lecheras. **Objetivo:** Evaluar el efecto de sustituir el heno de maíz con heno de girasol y garbanzo sobre el rendimiento y composición nutricional de la leche de cabra. **Métodos:** En este estudio participtivo, un total de 28 cabras multíparas lecheras Saanen fueron asignadas aleatoriamente a dos tratamientos (14 cabras a cada uno) durante 30 días en una finca pequeña. Dos semanas antes del experimento todas las cabras recibieron una dieta de adaptación. Un tratamiento (MZST) recibió una dieta convencional de heno de alfalfa (200g/cabra/día) y concentrado (400 g/cabra/día), más 600 g/cabra/día (50% de la ración) de heno de maíz. El segundo tratamiento (SFCPT) tuvo el mismo contenido de alfalfa y concentrado, pero con 600 g/cabra/día de heno de girasol-garbanzo. Se registraron los rendimientos y composición de leche, peso vivo y condición corporal de las cabras para cada tratamiento. **Resultados:** SFCPT incrementó significativamente el rendimiento de leche, y contenido de proteína y sólidos, pero no hubo diferencias en contenido de grasa. **Conclusión:** La suplementacion dietaria de cabras con heno de girasol y garbanzo aumenta la producción de leche y su contenido de proteína y sólidos totales en comparacion con el heno de maiz.

Palabras clave: *alimento; cabras; caprinos; composición química; forrajes alternativos; heno; girasol; garbanzo; leche; leguminosa; México.*

Resumo

Antecedentes: Os sistemas de produção animal em pequena escala têm um papel importante no fornecimento de alimentos de qualidade para atender uma demanda mundial crescente desses produtos, para melhorar a subsistência rural e para reduzir a pegada ambiental. Há uma necessidade, porem, de aumentar a produtividade através de estratégias de alimentação melhoradas. O girassol é nativo do México e o grão-de-bico é uma cultura comum na área de estudo que podem representar uma alternativa na alimentação de caprinos leiteiros. **Objectivo:** Avaliar através de investigação participativa na exploração o efeito da substituição da palha de milho tradicionalmente utilizada na alimentação de cabras leiteiras por uma forragem alternativa adaptada à região, mas não utilizada até o momento, em termos de rendimento, composição química de leite fresco de cabras. **Métodos:** Vinte e oito cabras leiteiras Saanen multipares foram designadas aleatoriamente a dois tratamentos (14 cabras/tratamento), em um experimento de 30 dias numa fazenda de pequena escala. Duas semanas antes do experimento, todos os caprinos receberam uma dieta de adaptação. Um tratamento (MZST) recebeu a dieta convencional de feno de alfalfa (200 g/caprino/dia) e concentrado (400 g/caprino/dia) mais 600 g/caprino/dia (50% da ração) de palha de milho. O segundo tratamento (SFCPT) tinha a mesma proporção de alfalfa e concentrado, mas com 600 g/caprino/dia de feno de girassol e grão-de-bico. O rendimento e composição do leite, o peso vivo e a condição corporal das cabras foram registrados de cada tratamento. **Resultados:** SFCPT aumentou significativamente o rendimento do leite e o conteúdo de proteínas e sólidos, mas não houve diferença no conteúdo de gordura láctea. **Conclusão:** O tratamento com girassol e feno de grão de bico aumentou a produção de leite, o teor de proteína e os sólidos totais.

Palavras-chave: *bode; cabras; comida; composição química; feno; forragens alternativas; girassol; grão de bico; leite; leguminosas; México.*

Introduction

Small-scale livestock systems ameliorate rural poverty (FAO, 2010), but must adapt the feeding strategies of their herds and flocks to new scenarios in the face of current challenges (Shikuku *et al*. 2016). Goat systems may lead to sustainable rural livelihoods (Daskiran *et al*. 2018), but have low productivity due to low quality and availability of feeds, low genetic merit of stock, and low milk yields (Souza *et al*. 2017). Improving goat diet can enhance productivity; a necessary move to improve livelihoods (Makkar, 2016). Quality forages may have positive impact on milk yields (Cabral *et al*. 2015) and, if home-grown, improve efficiency in the use of resources (Rao *et al*. 2015).

The association of legumes with grasses or other forage plants has environmental, agronomic and economic benefits, as legumes improve soil fertility through nitrogen fixation, promotes soil conservation, reduces weed invasion, improves yields, and enhances the protein content of forages (Maxin *et al*., 2016). Therefore, research in forage production with locally adapted legumes and other forage plants is warranted.

Mexico is the 12th largest goat milk producer worldwide, with 68% extensive or semi-extensive and 32% intensive farms (SIAP, 2020). Goat feeding in extensive or semi-extensive farms is based on grazing of natural grasslands and shrub browsing, while intensive systems are based on lucerne, concentrates, and crop residues such as corn straw (Salinas *et al*. 1999; Fuentes *et al*. 2001).

Corn straw is high in fiber and low in digestibility and protein (Fuentes *et al*. 2001). On the other hand, sunflower (*Heliantus annus*) is rich in lipids (Rodrigues-Gandra *et al*. 2017) and has been used to increase the fat content of diets, which in goats has resulted in increased milk protein content (Sanz-Sampelayo *et al*. 2007). Sunflower is native of México and is adapted to several climates in the country.

Chickpea (*Cicer arietinum*) is a legume cultivated mostly for its pulse-grain for human consumption (Herrera-Flores *et al*. 2019). As a legume, chickpea fixes atmospheric nitrogen, improving soil fertility. Mexico is the third largest producer of chickpea worldwide, and the study area of the work herein reported is the fourth producer in the country. Both sunflower and chickpea are not traditionally used as feed for goats, but could represent an alternative option to improve the diet quality and productivity of dairy goats.

Therefore, the objective of this study was to evaluate through participatory on-farm research the effect of substituting corn straw traditionally used for feeding dairy goats with a better-quality forage based on sunflower and chickpea hay on the yield and chemical composition of goat milk.

Materials and Methods

Ethical considerations

The experimental procedures followed guidelines by Instituto de Ciencias Agropecuarias y Rurales (ICAR) of Universidad Autónoma del Estado de México (Mexico), and were institutionally approved (DICARN-1319).

The study followed an adaptive participatory rural research approach methodology validated in different countries (Kraaijvanger and Veldkamp 2015; Flor *et al*. 2017), where the main goal is to find solutions to problems faced by farmers through collaborative work between farmers and researchers promoting innovation in the utilization of local resources (Hauser *et al*. 2016; Aare *et al*. 2021).

Location of the study

The on-farm experiment, following the participatory livestock technology development approach, was performed in Yuriria, state of Guanajuato 20° 12' 51" N and 100° 08' 19" W in central Mexico. The region is a plateau with a mean altitude of 2000 masl, a semi-warm sub-humid climate with rains in summer and a dry season in winter, and a mean rainfall of 600-700 mm/year.

Sunflower-chickpea hay

The sunflower intercropped with chickpea was sown after a corn crop on 1.0 ha on September 2nd 2018, towards the end of the rainy season and harvested on December 20th at 109 days post sowing. The sowing rate was 10 kg seed/ha (estimated density: 80,000 plants/ha) of sunflower (cv. Tiacaque) and 75 kg/ha (90,000 plants/ha) of a local landrace chickpea seed. The distance between rows was 80 cm, and distance between plants was 15 cm. At harvest, the sunflower was at the R8 phenological stage (Schneiter and Miller, 1981) and chickpea at the R7 stage (Herrera-Flores *et al*., 201), and both were left to dry in the field (for 96 h), after which all material was ground through a 2.5 cm sieve with a tractor-driven hammer mill. The final proportion of each forage was 60 sunflower and 40% chickpea. Crop yield was approximately 7.5 tonnes DM of field-cured dried sunflower-chickpea hay (SFCP).

Animals

The experiment was conducted with 28 multiparous Saanen dairy goats, randomly divided into two groups of 14. Goats were in late lactation (195±11 days in milk).

Initial conditions were as follows: 58±3.2 kg live weight, 1.2±0.2 kg daily milk yield, and 6 body condition score (BCS) on a scale from 1 (very thin) to 9 (very fat) (Aumont *et al*. 1994). Analysis of variance was performed on goat live weight before starting the experiment to determine if there were significant differences between both groups; no differences were observed; therefore, a completely randomized design was deemed adequate.

The animals were housed in open pens (one pen per treatment group) with dirt floor and roofed in one third of the area, covering above the feeding troughs, which ran the whole width of the pen. The feeding area had a 1.0 m concrete floor along the feeding troughs. Each pen was 7.5 x 8.0 m, providing ample space for each goat group (4.3 m^2/goat).

The forage treatments and lucerne hay were fed to each treatment group collectively, and the concentrate supplement fed individually to each goat at milking. Goats were milked by hand once a day at 7:00 h.

Two weeks prior to the commencement of the experiment, all goats in the flock received an adaptation diet that included the concentrate supplement to be used during the experiment at 400 g/goat/day, and 200 g/goat/day of lucerne hay, and 600 g/goat/day of a 50:50 (fresh basis) mixture of corn straw and sunflower-chickpea hay, plus minerals and water *ad libitum*.

The experimental treatments MZST or SFCPT were implemented in each of the groups at the beginning of the trial. Milk yield for each goat was recorded daily, and a 20-ml milk sample from each goat was daily taken and refrigerated (3 °C), with a weekly pooled sample analyzed for milk composition. Mean values were used for analyses.

Live weight (LW in kg) was recorded on the first and last day of the experiment with a hook digital scale, and body condition score (BCS) was assessed simultaneously by the same observer during both weight recordings.

The experiment took place from June 10th to July 9th, 2019 (30 days). The length of the experiment was decided in consultation with the participating farmer taking into consideration his flock management needs as well as sufficient time to evaluate the effect of the experimental feeding treatments. The response to a diet by dairy ruminants can be observed after a few days of the diet introduction, and short experimental periods in feeding experiments for dairy goats are well validated and accepted in the scientific literature, as demonstrated by Charpentier *et al*. (2019). Thus, a 30-day experiment was appropriate to detect potential effects of the treatments.

Diets

Treatment MZST, the conventional diet (control) consisted of concentrate, lucerne hay, and corn straw; whilst the experimental treatment (SFCPT) was concentrate, lucerne hay, and sunflower-

chickpea hay replacing the corn straw. The forages (lucerne hay, corn straw and sunflower-chickpea hay) were ground with a hammer mill through a 2.54 cm screen.

Diets provided 67% forage (lucerne hay plus corn straw or sunflower-chickpea hay) and 33% concentrate, with water and a commercial mineral plus vitamin mix for goats provided *ad libitum*.

The concentrate supplement was a homemade mix of commercial compound concentrate for dairy goats with 22% CP (65% fresh weight), ground white corn grain (20% fresh weight), and ground sorghum grain (15% fresh weight), with 18% final CP content for the mixture.

Table 1. Composition of treatment diets on a dry weight basis (g DM/goat/d).

Ingredient	MZST	SFCPT
Concentrate	400	400
Lucerne hay (ground)	200	200
Corn straw (ground)	600	0
Sunflower – chickpea hay (ground)	0	600
Total	1,200	1,200

DM: Dry mater; MZST: concentrate+lucerne hay+corn straw; SFCPT: concentrate+lucerne hay+sunflower-chickpea hay.

The concentrate was provided individually to each goat at milking, and the ground lucerne hay and experimental forages (corn straw or sunflower-chickpea hay) were thoroughly mixed before allocation to the goats to minimize selection and offered collectively to each experimental group of goats (Table 1), offering half of the forage ration in the morning and the other half in the afternoon. Every morning, refusals were collected before a new allocation of forages, then weighed, and a sample taken for determination of dry matter content.

Samples of the experimental diets (forage plus concentrate) were taken daily before allocated, and samples of the individual ingredients taken weekly for chemical analyses.

Both treatments met the requirements for energy and protein of milking goats (NRC, 2007). However, the diets were not isoproteic nor isoenergetic since the objective of the study was not to compare the two forage sources (MZST or SFCP) on a nutritional basis. The objective was in line with what Rao *et al*. (2015) described as the need to improve feeding strategies for small-scale livestock systems based on quality forages to increase productivity to better contribute to sustainable livelihoods and to meet world challenges for livestock production.

Chemical composition of feeds

Samples were dried at 55 °C for 72 hours in a draught oven and then milled through a 1 mm sieve. Samples of all feeds were analyzed for ash by incineration at 550 °C (AOAC, 1990) to determine organic matter (OM), crude protein (CP) by the Kjeldahl method (N x 6.25), and ether extract (EE), following AOAC (1990) procedures. Neutral detergent fiber (NDF), and acid detergent fiber (ADF) following Van Soest *et al*. (1991). *In vitro* dry matter digestibility (IVDMD) followed the method of Tilley and Terry (1963), with rumen fluid obtained through a stomach tube from five donor female goats.

Milk sampling and analyses

Milk yield for each goat was recorded daily. A 20-ml sample of milk from each goat was taken daily, pooled by treatment, and refrigerated (3 °C) before being analyzed for milk composition, determined with an automatic ultra-sound milk analyzer (Lactoscan MCC).

Samples were pooled by treatment due to restraints in the on-farm adaptive experiment with the collaborating farmer as the milk analyzer was facilitated by the farmers' association only once per week. This illustrates one of the limitations of the adaptive research approach followed in this experiment, with the goal of adapting a given technology to local conditions through in-farm experiments (Flor *et al*. 2017).

Adaptive research not only applies existing knowledge; research with farmers investigates how results adapt to the farmer objectives and productive conditions to facilitate dissemination and adoption of results (Stroup *et al*. 1993).

Compared to experimental centers, on-farm research with small-scale farmers faces limitations like small land holdings, small herds or flocks, and management constraints to carry out the experiments; but these are offset by the benefits of participatory research, as stated by Stroup *et al*. (1993).

Statistical analyses

Variables for goat performance and milk composition were analyzed with ANOVA (Minitab 14 statistical software) following a completely randomized design with the following model:

$$Y_{ij} = \mu_i + t_j\ e_{ij} \quad (1)$$

Where: μ= general mean, t= effect of treatments (i = 1, 2) and e= residual variation. Analyses for variables were on the mean values. Significant differences were declared at $p \leq 0.05$.

Results

Chemical composition of feeds

Sunflower-chickpea hay combines an oil plant and a legume, resulting in a forage high in crude protein content and high ether extract (lipid) (Table 2). The total diet (SFCPT) was thus 33% higher in CP, 75% higher in EE, and 15% higher in IVDMD than the control diet (MZST).

Animal variables

Milk yield in SFCPT with sunflower-chickpea hay was significantly higher ($P<0.001$) at 10% more than the control diet (MZST), and there was a significant increase ($P<0.05$) in protein, total solids, and non-fat solids content over the conventional ration (MZST) (Table 3).

Table 2. Chemical composition of feeds and treatment rations (MZST and SFCPT) (g/Kg MS).

	DM	OM	CP	NDF	ADF	IVDMD	EE
CON	967.07	903.25	179.58	285.12	79.21	827.20	20.00
LH	880.14	900.15	180.47	360.61	280.52	670.41	22.51
MS	894.14	933.59	59.63	720.50	460.56	530.63	28.17
SFCP	694.07	890.07	173.39	425.24	270.32	678.42	171.22
MZST	910.57	911.33	143.69	618.53	364.45	605.32	28.43
SFCPT	820.93	892.82	211.95	441.32	250.62	694.23	113.72

CON: Concentrate; LH: Lucerne hay; MS: Corn straw; SFCP: Sunflower-chickpea hay; MZST: CON+LH+MS; SFCPT: CON+LH+SF-CP; DM: Dry matter; OM: Organic matter; CP: Crude protein; NDF: Neutral detergent fiber; ADF: Acid detergent fiber; IVDMD: *In vitro* dry matter digestibility; EE: Ether extract.

Table 3. Productive response of goats, milk composition, live weight, dry matter intake and forage refusals by treatment.

	MZST	SFCPT	SEM	P-value
Milk yield (kg/goat/day)	0.97	1.07	0.01	0.001
Milk fat (g/kg)	33.81	34.50	0.54	0.215
Milk protein (g/kg)	33.19	34.50	0.55	0.050
Total solids (g/kg)	121.14	122.96	1.02	0.017
Non-fat solids (g/kg)	89.81	94.00	0.90	0.001
Live weight change (kg)	2.64	3.66	0.26	0.009
Body condition score	6.27	6.44	0.23	0.152
TDMI (kg DM/goat/day)	1.07	0.95	0.06	0.001
Forage refusal (kg DM/goat/day)	0.12	0.24	0.12	0.001

MZST: concentrate + lucerne hay + corn straw; SFCPT: concentrate + lucerne hay + sunflower-chickpea hay; TDMI: total dry matter intake; SEM: standard error of the mean.

There were no significant (P>0.05) changes in body condition score, but the SFCPT treatment showed a significant (P<0.009) 1.02 kg higher live weight gain during the experiment than that for goats on the MZST treatment.

Total dry matter intake was 11.2% higher (P<0.001) in the conventional MZST ration than in the SFCPT treatment, and refusals were also significantly (P<0.001) higher at 0.24 kg DM/goat/day in the SFCPT treatment compared to 0.12 kg DM/goat/day in MZST.

Discussion

Feeding dairy goats with hay from sunflower intercropped with chickpea led to higher animal performance compared to the conventional diet based on corn straw, highlighting the prospects for improving the productivity of these systems as reported by Rao *et al*. (2015) and Makkar (2016).

The decision to associate sunflower and chickpea stemmed from the benefits of legumes associated with other crops not only in terms of forage quality for animal feed, but also for agronomic, economic, and environmental benefits (Maxin *et al*. 2016) given by the nitrogen-fixing capacity of legumes.

However, no references were found on the use of this association as animal feed, so reference is done to literature on the use of sunflower or chickpea monocrops to contrast and discuss the findings of the present study.

Chemical composition of diets

Corn straw has been described as a roughage high in fiber, with low digestibility and poor protein content (Fuentes *et al*. 2001), as observed in this experiment.

On the other hand, sunflower-chickpea hay had better nutritive quality, with less NDF and ADF compared to corn straw, and a higher content of CP and EE resulting in 28% higher IVDMD (Table 2).

Ether extract and CP contents of sunflower-chickpea hay were lower compared to other reports evaluating sunflower as a forage source (Rodrigues-Gandra *et al*. 2017; Sainz-Ramírez *et al*. 2020), in spite of being harvested at similar stage of maturity; but fiber contents were lower to values reported for sunflower silage by Guney *et al*. (2012) and Aragadvay-Yungán *et al*. (2015).

Sunflower forage is high in fiber and has low digestibility (Demirel *et al*. 2009) compared to other forages. Forages with high fiber content reduce ration digestibility, synthesis of rumen microbial protein and energy supply (Gottardo *et al*. 2017). The association of sunflower with chickpea, however, resulted in lower fiber content than sunflower in monoculture (Table 2) given that chickpea forage is low in fiber (Herrera-Flores *et al*. 2019). Nonetheless, in spite of its lower fiber content, the experimental SFCPT ration showed lower dry matter intake, perhaps due to a higher concentration of lipids in the diet (28.4 g/kg DM in MZST vs. 113.7 g/kg DM in SFCPT).

Milk yield and composition

A report by Sanz-Sampelayo *et al*. (2007) suggested that increased dietary lipids do not affect net energy intake or milk yield in goats, but positively affect milk fat content, which was not observed in the current experiment. Dietary inclusion of energy foods increases microbial protein synthesis in the rumen as well as propionic acid concentration, thus increasing milk production (Hills *et al*. 2015; Vicente *et al*. 2017). In spite of lower DM intakes, this effect was observed in the SFCPT ration where sunflower seeds in hay with high lipid content (Rodrigues-Gandra *et al*, 2017) may have favored the increase of milk yield in the SFCPT diet.

Contrary to reports by Chilliard *et al*. (2003), who did not observe differences in milk yield when supplementing the diet of milking goats with 3% fish oil in mid and late lactation, milk yield in the present study was higher in the SFCPT treatment.

Diet composition does influence milk composition in dairy goats due to factors such as energy intake (Sanz-Sampelayo *et al*. 2007;

Sanz-Ceballos *et al*. 2009). High-energy feeds increase fat and protein content in milk (Kalač and Samkora, 2010), although only the increase in protein was significant in the present study, with no significant effect on milk fat.

Milk fat is the component most susceptible to changes in the diet and of great importance for assessing milk quality. Kalač and Samkora (2010) and Gottardo *et al*. (2017) found a positive correlation between dietary protein and fat content in milk. Nevertheless, no significant differences between treatments for milk fat content were observed in the present study even though SFCPT had over 47% higher CP content than MZST.

The effect of supplementary fat in the diet on fat secretion in milk has a minor effect in mid and late lactation compared to early lactation (Chilliard *et al*. 2003) due to anabolic enzymes effects on the adipose tissue involved in *de novo* milk-fat synthesis, as well as to lipase lipoproteins activity after the peak of lactation (Soryal *et al*. 2004; Deshwala *et al*. 2020).

Results from the present experiment were similar in terms of milk fat and protein to a report by Zucali *et al*. (2007) supplementing sunflower seeds to dairy goats at the peak of lactation; whilst Arco-Pérez *et al*. (2017) reported higher milk fat and protein contents in goats after parturition when including sunflower oil in the diet.

It was also notable that goats on SFCPT showed a liveweight gain 38.6% higher than on MZST, although no change in body condition was observed.

In conclusion, our results show that feeding dairy goats with a SFCPT diet based on sunflower-chickpea hay increases milk yield and live weight gain.

Declarations

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Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

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Author contributions

Aurora Sainz-Ramírez conducted the research, laboratory analyses, writing - original draft. José Velarde-Guillén contributed to the methodology, writing - review and editing. Julieta Gertrudis Estrada-Flores contributed to the methodology, writing - review and editing. Felipe López Gonzalez contributed to the methodology, statistical analyses, writing - review and editing. Carlos Manuel Arriaga-Jordán contributed to the conceptualization, resources, writing - review, editing and translation, supervision and funding acquisition.

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