Agroind. sci. 14(1): 63-69 (2024)

Agroindustrial Science

Website: http://revistas.unitru.edu.pe/index.php/agroindscience

Escuela de Ingeniería Agroindustrial

Universidad Nacional de Trujillo

Inclusion of by-products of the brewing and wine industry in dairy goats

Inclusión de subproductos de la industria cervecera y vitivinícola en cabras lecheras

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ABSTRACT

The aim of the following work was to evaluate a diet formulated with byproducts from the brewing and wine industry for lactating goats and quantify its potential in terms of nutritional quality and quantity. Twelve multiparous Nubian x Saanen goats, 2.75 years old (+ 1,24) during an experimental period of 12 weeks: 2 weeks of habituation and 10 weeks of testing. In both diets the goats grazed 6 hours on natural grass. Diet T0 (n = 6): Commercial feed: 500 g/day/goat (16% CP and 2.6 Mcal ME/kg DM) and diet T1 (n = 6): non-traditional balanced feed: 500 g/day/goat (16% CP and 2.6 Mcal ME/kg DM). Productive performance and health parameters were evaluated in goats fed with both diets during a period of 5 weeks starting 35 days postpartum. Total dry matter intake (DMI), milk production and corrected (MY and MYC), live weight (BW), body condition score (BCS), degree of FAMACHA© and quantitative coproparasitological diagnosis (EPG and OPG) were measured. A greater DMI was observed at T0 compared to T1 ($p < 0.05$). MY, MYC, BW, BCS, FAMACHA©, EPG and OPG did not show significant differences ($p > 0.05$) between both diets (T0 vs T1) throughout the experimental period evaluated. Goat health parameters throughout the study were within the physiological range during the production cycle and did not interfere with dietary treatments. The formulation of the diet with barley bagasse and grape pomace in dairy goats had a productive behaviour and health parameters like those of the commercial diet evaluated, without affecting milk production.

Keywords: Barley bagasse; caprine; grape pomace; health parameters; milk yield.

RESUMEN

El objetivo del estudio fue evaluar una dieta formulada con subproductos de la industria cervecera y vitivinícola para cabras en lactancia y cuantificar su potencial en términos de calidad y cantidad nutricional. Se utilizaron 12 cabras multíparas Nubian x Saanen de 2,75 años (+1,24) durante un período experimental de 12 semanas: 2 semanas de habituación y 10 semanas de prueba. En ambas dietas las cabras pastaron 6 horas en pasto natural. Dieta T0 (n = 6): Alimento comercial: 500 g/día/cabra (16% PB y 2,6 Mcal EM/kg MS) y dieta T1 (n = 6): Alimento equilibrado no tradicional: 500 g/día/cabra (16% PB y 2,6 Mcal EM/kg MS). Se evaluó el rendimiento productivo y los parámetros sanitarios de las cabras alimentadas con ambas dietas durante un periodo de 5 semanas a partir de los 35 días postparto. Se midió el consumo total de materia seca (CTMS), la producción de leche y corregida (PL y PLC), peso vivo (PV), la puntuación de condición corporal (CC), el grado de FAMACHA© y el diagnóstico coproparasitológico cuantitativo (HPG y OPG). Se observó un mayor CTMS en T0 en comparación con T1 ($p < 0,05$). PL, PLC, PV, CC, FAMACHA©, HPG y OPG no mostraron diferencias significativas ($p > 0,05$) entre ambas dietas (T0 vs T1) a lo largo del periodo experimental evaluado. Los parámetros de salud de las cabras a lo largo del estudio estuvieron dentro del rango fisiológico durante el ciclo productivo y no interfirieron con los tratamientos dietéticos. La formulación de la dieta con bagazo de cebada y orujo de uva en cabras lecheras tuvo un comportamiento productivo y parámetros de salud similares a los de la dieta comercial evaluada, sin afectar la producción de leche.

Palabras clave: Bagazo de cebada; caprino; orujo de uva; parámetros sanitarios; producción de leche.

Recibido 12 enero 2024
Aceptado 11 abril 2024

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DOI: http://doi.org/10.17268/agroind.sci.2024.01.07

1. Introduction

Today, scientists consider the "Anthropocene", the era where humans are the main intervening force on the planet, through progress and the development of production and industrialization processes, among others, to have been inaugurated (Borrelli, s.f.). These problems of global scale, mark the need for awareness of the irrational use of goods and services, and of the productive systems carried out. Feed is a determining factor in animal production as it represents 70% of the costs, therefore, a possible strategy is to use waste from different regional industries to reduce dependence on cereals, the production of which is one of the main causes of deforestation, soil deterioration and loss of biodiversity (Sivilai & Preston, 2019). Therefore, animal production systems face the challenge of developing feeding alternatives that allow for profitable, sustainable, and environmentally friendly systems without relying on external resources.

The brewing industry uses barley (Hordeum vulgare) as raw material and generates barley bagasse, this by-product is the result of the pressing and filtering process of the wort obtained after saccharification of the malted cereal grain, which is generally moist, highly palatable and perishable, rich in protein with intermediate degradability and fibre. It is considered, from a nutritional point of view, as a very interesting ingredient in rations (Fernández, 2010; Arias et al., 2017; Landau et al., 2023; Battelli et al., 2024). It is a product with a dry matter content of 20-25%, crude protein 24-26%, ethereal extract 6%, NDF 44% and FAD 20%, although these last two fractions (NDF and FDF) contribute little effective fibre (18%) (Davis, 2008). According to data obtained by Fernández (2010), bagasse derived from the industrial brewery produced DM, CP and ME values of 16-32%, 30.5% and 2.39 Mcal, respectively. Grape pomace is a by-product of the wine industry obtained from the vinification process, which consists of subjecting the fruit to a juice extraction process. The part resulting from pressing is called grape pomace and consists of pulp, seeds and skins and is estimated to constitute 12% of the weight of fresh grapes and has a moisture content of 65%. It is composed of approximately 45% skin, 30% seeds and 25% stems (Arias et al., 2017; Dávila et al., 2017). Depending on the growing region and vine varieties used, pomace can have approximately the following chemical composition, 12-14% protein, 17-35% crude fibre, 5-9% fat, 5-9% minerals (Arias et al., 2017; Dávila et al., 2017). Although it is a low-quality resource, high in fibre and low in energy, it is recommended for feeding cattle, goats, or non-lactating animals (Arias et al., 2017; Landau et al., 2023; Battelli et al., 2024).

During the last two decades, the agro-industrial wine and beer sector has grown and become an important sector, generating a large amount of waste. These agro-industrial by-products and crop residues can play an important role in the feeding of goats in different production systems. Such residues can supply a substantial part of the maintenance and milk production needs of goats in the country (Steffen et al., 2019). Furthermore, it has been reported in the literature that some biologically active compounds, such as phenolic compounds contained in these by-products, have potential natural anthelmintic activity, and may be an alternative to reduce the use of synthetic chemicals in animal production (Nudda et al., 2019; Landau et al., 2023). For correct interpretation in view of the potential effects of experimental dietary treatments (Nudda et al., 2019), clinical examination, body condition scoring, degree of FAMACHA© and coproparasitological evaluation of animals is essential to assess the physiological and health status of farm animals (Rossanigo & Page, 2017; Steffen et al., 2022; Smith & Sherman, 2023).

However, information on the quantity and availability of these by-products and the combination of both in the implementation in livestock diets is scarce. Moreover, although there are few studies on the implementation of these by-products for livestock production, in small ruminants and in lactating goats in our country, it has not yet been tested.

This study has developed a diet formulated with by-products from the brewing and wine industry for animal feed and quantified its potential in terms of nutritional quality and quantity, as well as its use for milk production in lactating goats. The research described in this paper is part of an overall strategy that aims to make better use of feed resources for the benefit of small-scale farmers and the environment.

2. Materials and Methods

2.1 Farms and animals under study

The study took place in the Caprine Experimental Unit of the Faculty of Agricultural and Forestry Sciences of the National University of La Plata, province of Buenos Aires, Argentina during 2022. Twelve multiparous Nubian x Saanen goats, 2.75 years old (± 1.24), were used during an experimental period of 12 weeks: 2 weeks of habituation and 10 weeks of testing. In both treatments, the goats grazed 6 hours of natural grass. Once the grazing hours were over, a corral was assigned to each treatment (8 animals in each) and the corresponding hay was offered.

Two treatments were carried out:

- T0: Commercial feed: 500 g/day/goat (16% CP and 2.6 Mcal EM/Kg DM).
- T1: Non-traditional balanced feed: 500 g/day/goat (16% CP and 2.6 Mcal EM/Kg DM).

The T1 had 70% Barley bagasse, 11% Grape pomace and 19% corn grain. The red grape variety (*Vitis labrusca,* var. *Isabella*) from the coastal area of Berisso in Greater La Plata, Buenos Aires province, Argentina, was investigated. The nutritional composition of the different feeds (barley bagasse, grape pomace, and corn grain) that made up the T1 formulation are shown in Table 1.

2.2 Evaluation of productive performance and health parameters

Intake and live weight: Total dry matter intake (DMI) was estimated by the formula DMI = 533 + (305.2 x MY) + (13.3 x BW) according to Sauvant et al. (1991). Where: MY = milk yield (l) and BW= live weight. A mechanical column scale with weights (maximum capacity 600 kg) was used to determine the live weight (BW). The MY values were obtained from the corresponding dairy controls. On the other hand, at the time of milking and during one-week, individual intake (difference between delivered and rejected expressed in kg DM) of T0 and T1 was measured.

Dairy control: Milk yield (MY) was measured once a week using individual milk meters expressed as l/day/goat for a period of 5 weeks after 35 days postpartum and then converted to millilitres (ml). MY was corrected (MYC) for butterfat (BF) and crude protein (CP) according to the formula below (Mancilla-Leytón et al., 2021): MYC (BF=3.70 CP=3.7) (l/d) = $MY * [(0.12 * BF+0.10 * CP+0.23)]$ Where: MYC = milk yield corrected for fat and protein expressed in litres per day. MY = milk yield (l); BF = milk butterfat content (%); CP = milk crude protein content (%).

Body condition score (BCS): BSC was assessed postpartum and in early, mid, and late lactation, before each milk control. Briefly, BCS was performed by palpation in the lumbar region, sternal and base of the tail and were categorised into: Skinny: 0 to 2.75 points; Good: 3 to 3.75 points; and Obese: 4 to 5 points, as previously described (Steffen et al., 2022).

Degree of FAMACHA© (FAMACHA©): The degree of FAMACHA© was assessed postpartum and at the beginning, middle and end of lactation, before each milk control. Briefly, the degree of FAMACHA© according to the colour of the palpebral conjunctiva was established, and goats were categorised into 3 groups: Acceptable: grades 1 and 2; Intermediate: grade 3; Risky: grades 4 and 5, as previously described (Steffen et al., 2022).

Quantitative coproparasitological diagnosis: Faecal samples were taken randomly from all goats during postpartum and at the beginning, middle and end of lactation, before each milk control in both treatments. A quantitative copro-parasitological diagnosis was performed using the modified McMaster technique, determining the number of strongylid nematode eggs per gram of faecal material (EPG) and coccidian oocysts per gram of faecal material (OPG). Infection levels with nematodes and coccidia were calculated as the number of positive animals over the sampled population and expressed as percentages.

2.3 Statistical analysis

The experimental design was completely randomised, with measurements repeated over time. For milk production, body condition score, FAMACHA© and coproparisitological analysis a multifactorial ANOVA was carried out, considering in addition to the treatment, the effect of the days of lactation. Comparisons between means were evaluated using the Tukey test. Differences were considered significant with a p value < 0.05 and trends between 0.05 and 0.10. The data were analysed using the MIXED Procedure (SAS, 2004).

3. Results and discussion

The nutritional composition of the commercial feed (T0) and non-traditional balanced feed (T1) is presented in Figure 1 and Table 1.

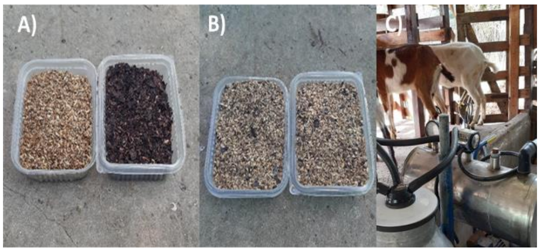

Figure 1. Formulation and consumption of T1 in lactating goats during mechanical milking. **References:** **A)** Dried barley bagasse and grape pomace; **B)** Final formulation; **C)** Consumption of the T1 formulation during mechanical milking of lactating goats.

Table 1
Nutritional composition of different foods

Ítem	DM % (SE)	CP % (SE)	EM Mcal (SE)	NDF % (SE)
Barley bagasse	33 (±1.25)	19 (±0.75)	2.72 (±0.06)	44.2 (±0.12)
Grape pomace	27 (±1.35)	11 (±0.35)	1.80 (±0.01)	63.8 (±0.27)
Corn grain	89 (±0.12)	8 (±0.26)	3.25 (±0.02)	14.0 (±0.33)
Commercial feed	89 (±0.31)	16 (±0.22)	2.60 (±0.01)	28.0 (±0.15)

References: DM: Dry Matter; CP: Crude Protein; ME: Metabolisable Energy; NDF: Neutral Detergent Fibre. SE: Standard error. Determined in the Laboratory of the Chair of Agroindustries, FCAyF-UNLP.

In relation to the individual consumption of T0 and T1, the foods were consumed in their entirety. A higher total consumption of dry matter was verified in T0 compared to T1 ($p < 0.05$) (Figure 2).

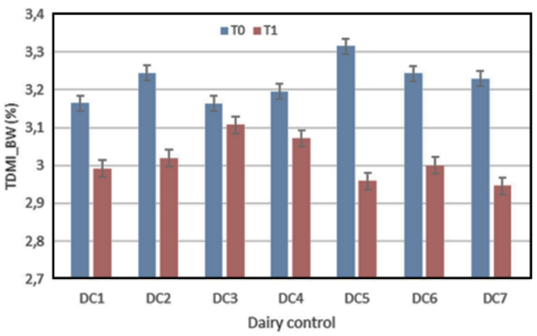

Figure 2. Total dry matter intake according to diet. **References:** TDMI_BW (%): Total dry matter intake in relation to live weight expressed as a percentage; T0: Commercial feed; T1: Non-traditional balanced feed; DC1-7: Dairy control.

The BW, MY and MYC did not show significant differences ($p > 0.05$) between the diets (T0 vs T1) throughout the experimental period evaluated (Table 2).

Table 2
Characteristics of the goats used in the experiment

Item	T0	T1	SE	p-value
Number of goats	6	6	-	-
Live weight (kg)	34.96	35.59	0.872	0.385
Milk yield (ml/day/goat)	985.61	984.95	17.449	0.976
Body condition score	2.53	2.51	0.026	0.565
FAMACHA©	2.70	2.96	0.045	0.501

References: Means followed by equal letters, in the rows, do not differ by Tukey's test, at 5% probability. Treatments: T0: Commercial feed; T1: Non-traditional balanced feed; SE: Standard error.

A greater trend (p = 0.098) was observed in milk production after 35 days of milking (5th milker control) and the average difference between both diets was 57.4 ml/goat throughout the evaluated lactation period (Figure 3).

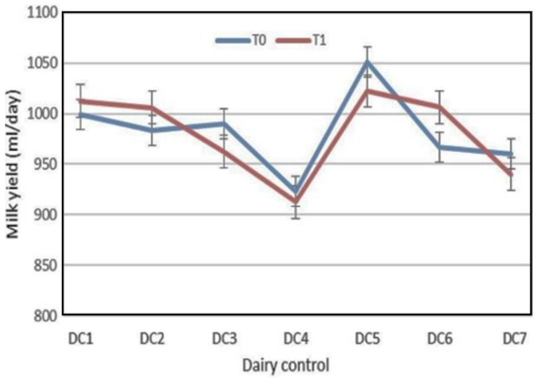

Figure 3. Milk yield (ml/day) of goats fed commercial feed and non-traditional balanced feed corrected for butterfat and crude protein. **References:** T0: Commercial feed; T1: Non-traditional balanced feed; DC1-7: Dairy control.

The BCS ranged between 2.60 and 3.05 and the lowest point was verified after 35 days of milking (p = 0.007), without significant differences between both treatments (p = 0,245) although the average BSC of the T0 treatment was slightly higher compared to T1. The FAMACHA© grade ranged from 2.40 to 3.50, with parturition being the highest risk stage. It was observed that most of the goats showed an Acceptable FAMACHA© grade, being slightly higher in T1 compared to T0, although without significant differences between both treatments (p = 0.382), and in milking days (p = 0.861). Parasitic infection rate was 100% (12/12) for strongylid nematodes and 75% (9/12) for coccidia. The highest EPG and OPG values were observed during parturition and 35 days after the start of milking. Mean EPG results for T0 and T1 were 392 and 303 respectively, with no significant differences between treatments (p= 0.392) and in days of milking (p=0.827). For OPG at T0 and T1 were 120 and 102 respectively (p=0.329) and with statistical differences (p=0.037) at 35 and 100 days of milking (153.05 vs 22.93, respectively). The highest average EPG and OPG values in T0 goats.

The nutritional composition of the non-traditional feed used in this work differed slightly from that reported in other studies, particularly in terms of protein and metabolizable energy content (Davis, 2008; Fernández, 2010). CP and EM values were 19% and 2.72 Mcal ME, respectively. This could be explained by the fact that the nutritional composition of barley bagasse is influenced by the standardised pressing and filtering practices of the wort obtained after saccharification of the malted cereal grain, and in grape pomace by viticultural practices and soil and climatic conditions, as well as by variety, maturity, and sanitary conditions (Davis, 2008; Ianni & Martino, 2020). The formulation of non-traditional balanced feedstuffs in the diet of lactating goats throughout the study period was very well received in terms of voluntary intake. In the present study, a lower intake was observed in the T1 group goats compared to T0, this could be due to the higher NDF content in the barley bagasse (44.2%) and grape pomace (63.8%) feeds used in the T1 diet formulation compared to commercial feed of T0 diet (14%), favouring a greater ballast effect (INRA, 2007) and substitution effect caused on forage intake (Arias et al., 2015). In fact, the feed intake of dairy goats was not compromised by the inclusion of by-products such as grape pomace or tomato unlike in sheep (Razzaghi et al., 2015; Modaresi et al., 2011; Nudda et al., 2019). However, other studies in ewes fed diets combined with by-products from the oenological industry consumed less dry matter daily compared to the diet without by-product (1.88 vs 1.79 in the dried grape pomace and 1.71 kg in the dried myrtle berry and dried tomato pomace groups) (Nudda et al., 2019). According to Correddu et al. (2023) in lactating ruminants, the inclusion of by-products (grape pomace, pomegranate, olive pomace and tomato pomace) in the ration, from 5% to 40% of dry matter (DM), did not depress milk, fat or protein production from cows, sheep, and goats. There are studies that show that the use of these by-products increases the percentages of butterfat and crude protein (López Sántiz et al., 2016; Nudda et al., 2019; Steffen et al., 2019; Echenique & Ozcariz, 2021). Although the chemical composition of the milk was not determined in this work, in previous studies by our team in this same Caprine Experimental Unit, Steffen et al. (2019) and Echenique & Ozcariz (2021) used wet bagasse from craft beer production in lactating goats, incorporating (500 g/day/animal), demonstrating an improvement in the chemical composition of milk and an increase in butterfat (4.25%) and protein (3.04%), without modifying the yield of milk production and the percentage of lactose. This is corroborated by the fact that the difference between the means of milk production during the whole lactation evaluated in both diets was 57.4 ml/goat. In another study, López Sántiz et al. (2016) used dry residues from beer production in diets in lactating goats and slightly improved milk fat percentage. It was also shown that the addition of 100 g/day of dehydrated grape pomace to the basal diet of sheep improved milk production and maintained the health status of lactating animals (Nudda et al., 2019).

Several studies corroborate that it is essential to assess the physiological and health parameters of production animals. In this sense, it has been shown that the severity of anaemia estimated by the FAMACHA© method, potentially caused by strongylid nematodes particularly Haemonchus contortus spp. and the evaluation of the body condition score would have a significant effect on the genesis and estimation of goat milk production losses (Rossanigo & Page, 2017; Steffen et al., 2022). BSC values, FAMACHA© and copro-parasitological assessment of goats on both dietary treatments were within the physiological range for goats throughout the period evaluated. In this trial the goats with the lowest BSC were found at the peak of lactation at 35 days, in both dietary treatments, which is to be expected, given that this is the period of highest metabolic and nutritional demand (Relling & Mattioli, 2013). In relation to FAMACHA© grade, Steffen et al. (2022) showed that goats belonging to the Risky group had the lowest daily milk production in contrast to goats in the Acceptable group which showed the highest milk production. In our study most goats were in the Acceptable group throughout lactation, although there was a slight variation around parturition. A possible explanation for this could be found in relation to the redistribution of blood flow due to gestation and parturition of the animals, although this did not affect lactation and thus milk production.

The literature has reported that the use of diets rich in biologically active compounds, especially polyphenols, is attributed with the ability to interfere with several biological mechanisms and positive effects on both animal production and human health and welfare are known (Ianni & Martino, 2020; Correddu et al., 2023; Landau et al., 2023; Battelli et al., 2024). Even grape pomace is a source of polyphenols, plays an important role in improving the nutritional value of animal products (Ianni & Martino, 2020; Correddu et al., 2023) and has a potential natural anthelmintic activity (Nudda et al., 2019; Landau et al., 2023). In relation to the coproparasitological values in our study, they remained below the reference values for anthelmintic treatment (Rossanigo & Page, 2017; Steffen et al., 2022; Smith & Sherman, 2023). On the other hand, no relationship can be established between the daily intake of the biologically active compounds contained in the non-traditional balanced feed diet with barley bagasse and grape pomace of treatment T1, as all animals were found with faecal parasite egg counts and oocysts below the recommended deworming values or indicative of subclinical parasite infection, i.e., they were in good health and apparently healthy. These data are consistent with the literature which states that parturition and peak lactation are physiologically stressful periods for production animals (Smith & Sherman, 2023). Therefore, in the present study, health parameters throughout the study were within the physiological range of the goats during the production cycle and did not interfere with dietary treatments (Steffen et al., 2022; Smith & Sherman, 2023).

Therefore, a feeding strategy based on supplementation of ruminants with by-products extracted from agroindustry seems promising (Correddu et al., 2023). In agreement with Sivilai & Preston (2019), it was possible to use different residues from regional industries as an alternative animal feed and allowed profitable, sustainable, and environmentally friendly animal production systems without relying on external resources.

4. Conclusions

Therefore, it can be concluded that the formulation of the diet with barley bagasse and grape pomace in dairy goats had similar production behaviour and health parameters to the control diet commonly used in commercial dairy farms, and that this diet could be used throughout lactation without affecting milk production.

In view of this, further studies on its use in the cheese industry as well as the comparison of costs and gross production margins are intended to be carried out in the future.

Acknowledgements

We would like to thank Orlando Gvozdriecki and José Meroni for their excellent technical assistance in working with the animals.

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