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ORIGINAL PAPER

Use of calcium carbonate (limestone) to dehydrate orange peel and its incorporation into sheep and goat diets*

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Abstract

The citrus industry produces a high amount of organic waste that contaminates the environment; using byproducts of this industry to feed small ruminants gives livestock farmers a socioeconomic advantage. The objective was to evaluate the drying of orange peel (OP) and the density of flies on it with different levels of limestone, and the performance in sheep and goats fed with a proportion of OP in a diet dehydrated with the inclusion of limestone. The results indicated that including 10% limestone decreased the proliferation of flies and dried the OP. The 50:50 amount caused more moisture loss and less fly proliferation in OP, but more limestone was wasted, and the calcium level in the formulated diet increased. Limestone inclusion improved the appearance of OP and visually decreased bagasse oxidation. Female lambs and goats were fed an energy ration with 10% OP dried with limestone, and conventionally, no significant differences ($p \geq 0.05$) in weight gain, feed consumption, and feed conversion were observed. The calcium and phosphorous content in the blood serum of the lambs and goats in this study indicates a normal status, and there were no significant differences ($P > 0.05$) between the groups. In conclusion, limestone as a source of $CaCO_3$ did not increase the economic cost of the diet; the proliferation of flies and the oxidation of OP were significantly reduced, making the preparation of the diets and their storage easier.

Keywords: lambs, goats, orange peel, limestone

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INTRODUCTION

Globally, sheep and goat meat livestock systems must be more efficient due to the increase in the human population (FAOSTAT 2020); for this reason, it is necessary to make good and efficient use of food byproducts that satisfy the nutritional requirements of the animals. Specifically, Africa and Latin America have the largest sheep and goat populations in marginalized regions with few technological and economic resources. The breeding of small ruminants on these continents is limited, making them less competitive than other domestic species. The diet of small ruminants is mainly based on grazing rangelands or communal lands, with poor quality forage abundant (Dias e Silva et al. 2020). Agro-industrial byproducts and waste are abundant and must be included in the diet of ruminants since there is increasingly little availability of high-quality grains and forages (Yafetto et al. 2023). Rafiq et al. (2018) suggest using citrus byproducts for feeding ruminants, highlighting the high production for domestic consumption since orange production is positioned as one of the best-selling agricultural products in the world for the citrus industry. The high output of oranges by the juice industry causes excess waste, reaching more than 76,292,600 tons annually (FAOSTAT 2020). Likewise, the environmental risk caused by fresh orange peel (OP) is due to high humidity and fermentative capacity, causing soil contamination by nitrites, nitrates and ammonium, in addition to increasing emissions of carbon dioxide (CO_2) and methane (CH_4) from the soil, which leads to public health disorders such as acute and chronic respiratory diseases (Sial et al. 2019).

OP is a byproduct widely used in livestock farming, which is given to farmers to feed the animals so that companies get rid of the product. The livestock industry tries to find conservation techniques to use OP efficiently in animal feeding, but the silage and dehydration processes are expensive. Finding suitable procedures for this food waste can be difficult due to its limited availability. Currently, other alternatives must be sought to dehydrate the OP so that it is not a contaminating byproduct when fresh, stimulating the breeding of insects and microorganisms that are pathogenic to the health of the animals. The hypothesis of this study indicates that OP flour dehydrated with limestone (a source of calcium carbonate) can be a feasible method to incorporate the byproduct into animal feed. This study aimed to integrate various levels of limestone mixed in the OP to evaluate its drying, inclusion in whole grain diets, and performance in sheep and goats.

MATERIALS AND METHODS

The research comprised two distinct phases, with the initial phase focusing on drying fresh OP using natural sunlight and limestone. In both groups, the density of flies was evaluated as contamination damage. The second phase evaluated the productive variables in lambs and goats fed with OP, which was dried directly in the Sun's rays and mixed with limestone. Both studies were conducted in the Rancho San José, situated at the north latitude of 19°24' and west longitude 98°11′, in a temperate subhumid climate, rainy summer, Tlaxcala, Mexico.

Phase 1. Evaluation of orange peel dried with limestone

Fresh OP was collected from 3 juice factories surrounding the ranch; the byproduct was selected carefully, without being contaminated with garbage or other byproducts used to prepare juices. The limestone ($CaCO_3$) was 100 mesh (sieved in 100 holes cm^{-2}), with a guaranteed analytical content of 38% calcium and 2% moisture.

The fresh OP was immediately divided into six treatments, each of 5 kg, being distributed as follows: a) OP without limestone (0%), b) OP mixed with 0.5 kg of limestone (10%), c) OP mixed with 1.0 kg limestone (20%), d) OP mixed with 1.5 kg limestone (30%), e) OP mixed with 2.0 kg limestone (40%) and f) OP mixed with 2.5 kg limestone (50%)

The limestone was mixed manually until perfectly impregnated in the fresh OP. The moisture loss in each treatment was evaluated every 48 hours for ten days. Each treatment was spread on a 3 m^2 plastic sheet inside a 20 x 10 m warehouse with a sheet roof at a height of 7 m. Ventilation was maintained throughout the day keeping an average temperature of 15°C. The Sun's rays lit all groups directly for 5 h per day. Moisture loss was measured in triplicate, and immediately after obtaining a sample, it was placed in a forced air oven for 48 h at a temp. of 70°C.

Furthermore, the presence of flies was quantified by direct observation of each treatment over a surface area of 30 cm^2. This was done every third day for 5 min, starting at 10:30 AM. Investation with flies was quantified as follows: 3 = high fly density (visual presence of more than 20 flies), 2 = medium fly density (visual presence of 10 flies), and 1 = low fly density (visual presence of 5 or fewer flies).

Phase 2. Growth performance and feed conversion

Two groups of species were used: twelve Saanen-Alpina French goats with an average weight of 17.87 ± 3.55 and twelve female Dorper lambs with an average weight of 22.39 Kg ± 3.85 selected for their corporal weight to be the most homogeneous. All animals were less than seven months old and considered an experimental unit. They received the same management, distribution, and performance of animal care guidelines from the ethics committee of Colegio de Postgraduados (enrollment 009-2023a). Animals were housed in individual raised pens with a slat floor height of 1.5 m, with individual feeders and bucket drinkers. The animals were randomly distributed (n=6) between the two treatments consisting of diets prepared with OP flour dried with 10% limestone and OP flour dried by sunlight and ventilated in the open air. The diets were formulated according to the requirements of the NRC (2007). Water and food were offered *ad libitum* and provided at 8.00 and 17.00 h. Before starting the tests, the animals were dewormed (Closantil® 5%), vaccinated (Exgon® *Pasteurella haemolytica*), and tagged with earrings. The animals were weighed using a digital scale (Rhino®, model BAC-300). The adaptation period to the diet was seven days. The duration of the experiment consisted of the fattening period of the animals, which was 56 days, and the body weight of the animals was recorded at the beginning and the end of the experiment. Feed consumption on a DM basis was recorded every 8d. Weight gain was calculated by subtracting the final weight from the initial weight. Daily weight gain (DWG) was calculated by dividing the total weight gain over the experiment period. Feed conversion was estimated between dry matter intake (DMI) and DWG. On the last day of testing, blood samples were taken from all animals were taken vacutainer needles into tubes with EDTA anticoagulant, keeping the samples refrigerated until analysis of blood calcium and phosphorus.

Laboratory analysis

The OP and diets were analyzed for moisture using a forced air oven at 55°C for 48 h, for ash – in a muffle furnace at 550°C for 18 h, and for crude protein – with the Kjeldahl method (AOAC 2005). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by digestion in neutral and acid detergent, respectively (Van Soest et al. 1991). The ashes were used for calcium and phosphorus analysis, carried out with the help of an Aanalyst 200 atomic absorption equipment, Perkin Elmer, and the calcium and phosphorus standards for obtaining the calibration curve were made from a standard solution, J.T. Baker.

Statistical analysis

In phase 1, the proportions of OP and limestone were analyzed with an X-Square test considering differences significant at $p \leq 0.05$. Phase 2, the analysis of the variables for the group of lambs and goats was separate. The statistical differences between each group with the control diets (sun-dried OP) *vs.* OP dried with 10% limestone were analyzed with Student's T test, considering a significant difference at $p \leq 0.05$, with the SAS statistical software version 9.4 (SAS 2013).

Table 1

Ingredients and chemical composition of the experimental diets

Ingredients (%)	Ration OPS	Ration OPL
Corn, grain	44.0	44.0
Waste of bread	5.50	5.50
Brewery root	9.0	9.0
Limestone	2.5	---
Orange peel, dried in the Sun	25.0	---
Orange peel, dried with limestone	---	27.5
Soybean paste	8.5	8.5
Tallow	2.0	2.0
Urea	1.10	1.10
Yogurt waste	1.9	1.9
Minerals	0.5	0.5
Nutrient composition analysis (%) based on DM		
Dry matter	88.96	88.96
ME (Mcal kg^{-1})	2.98	2.98
Fat	4.89	4.89
Crude protein	15.78	15.78
Neutral detergent fiber	12.48	12.48
Acid detergent fiber	4.84	4.84
Calcium	0.80	1.09
Phosphorous	0.62	0.71

OPS – orange peel, dried in the Sun, OPL – orange peel, dried with limestone, DM – dry matter

RESULTS AND DISCUSSION

Phase 1. Proportions of orange peel and limestone

The chemical analysis (%) of the OP was 79.8 moisture, 4.16 protein, 3.27 ash, and 1.3 phosphorus. Table 2 shows the evaluation results of different levels of limestone included in the OP. The greater inclusion of limestone increased the moisture loss ($P<0.05$). Meanwhile, the low fly proliferation and the increase in DM were better with 10% limestone. The 50:50 amount caused more moisture loss and less fly proliferation, but more limestone was wasted, and the calcium content in the formulated diet increased. Including limestone improved the OP's appearance and visually decreased bagasse oxidation (Figure 1).

Fig. 1. Visual differences in orange peel dried directly in the Sun and with the limestone mixture (photographs by first author)

Table 2

Moisture loss (%) in the treatments with orange peel (OP) and limestone

OP/ limestone	Days				
	2	4	6	8	10
100 / 0	21.31^{a}	24.02^{a}	25.89^{a}	27.86^{a}	29.52^{a}
Fd	3.0	3.0	3.0	3.0	3.0
90 / 10	42.74^{a}	53.33^{b}	61.05^{cd}	65.86^{d}	69.15^{d}
Fd	2.0	2.0	2.0	2.0	2.0
80 / 20	40.0^{a}	53.88^{b}	59.59^{bc}	66.85^{cd}	71.16^{d}
Fd	2.0	2.0	2.0	1.0	1.0
70 / 30	38.89^{a}	51.15^{b}	58.37^{bc}	64.73^{cd}	69.31^{d}
Fd	2.0	2.0	2.0	1.0	1.0
60 / 40	48.46^{a}	62.44^{b}	68.63^{bc}	74.68^{cd}	78.17^{d}
Fd	2.0	2.0	1.0	1.0	1.0
50 / 50	56.48^{a}	69.99^{b}	75.41^{b}	73.72^{b}	81.79^{d}
Fd	2.0	1.0	1.0	1.0	1.0

Fly density (Fd) 3 – high fly density (visual presence of more than 20 flies), 2 – medium fly density (visual presence of around ten flies), and 1 – low fly density (visual presence of 5 or fewer flies). Different letters between each row indicate significant differences ($P \leq 0.05$).

Phase 2. Growth performance and feed conversion

The growth performance in the lamb and goat groups (Table 3) did not show significant differences ($P > 0.05$). The measurement variables were feed consumption, DWG, and feed conversion.

Limestone was a good adjuvant in the OP drying process, and the calcium content in the diet increased by 0.23%. This value did not affect feed consumption and weight gain in goats and lambs. Another similar study, associated with orange byproducts (bagasse, peel, and silage) in beef cattle feeding, did not find differences in the productive variables and carcass yield either (Cabrera-Núñez et al. 2020). Citrus byproducts are even more efficient in rations when compared to fibrous forages.

Dairy goats on a diet including dehydrated orange peels increase milk fat without affecting feed consumption (Guzmán et al. 2020); this effect is

Table 3

Growth performance in small ruminants

Variables	Lambs			Goats		
	OPS	OPL	SE	OPS	OPL	SE
Initial weight (kg)	22.40	22.38	1.02	17.96	17.78	1.01
Final weight (kg)	30.19	29.99	1.08	24.51	24.34	0.99
Feed intake (kg/day)	1.020	1.006	0.22	0.862	0.893	0.18
Daily weight gain (kg/day)	0.139	0.136	0.01	0.117	0.117	0.02
Feed conversion	7.338	7.397	1.42	7.367	7.632	1.12
Blood mineral levels (mmol l^{-1})						
Calcium	2.88	2.93	0.34	2.77	2.89	0.29
Phosphorous	1.03	1.02	0.16	1.05	1.03	0.13

OPS – orange peel, dried in the Sun. OPL – orange peel, dried with limestone
There were no significant statistical differences between the group of lambs and the group of goats in the variables analyzed ($P \geq 0.05$).

due to the high level of NDF and pectin in OP. Pectin does not form lactic acid; consequently, acidosis is not induced when levels are commonly 100 to 150 g kg^{-1} in DM feed. The NDF content is essential in ruminant feeding; however, in citrus byproducts, the high pectin content is not part of NDF; this is an intermediate product classified in most concentrates and forages. Pectin is an energy source that increases the levels of acetic and propionic acids and the acetate/propionate ratio. Dried citrus pulp is also a valuable feed for growing livestock and has been partly replaced by energy sources at 20-30% DM levels. However, others cite (Arthington et al. 2002) inclusion of up to 40% of dried citrus pulp in the diets of fattening cattle without altering the animal's digestive function (Habeeb et al. 2017). In general, citrus fruits provide a variety of energy substrates for ruminal microbes, including soluble carbohydrates and quickly digestible NDF. Citrus byproducts improve nutrient digestibility, are viable for reducing the proliferation of *Salmonella* in the intestinal system and are food flavorings for ruminants (Callaway et al. 2008).

There is currently a lack of research comparing the impact of varying levels of OP and calcium on weight gain, feed consumption, and conversion rates in sheep and goats. Fresh OP appeared to be a more effective alternative to sorghum grain, significantly improving lambs' feed efficiency and weight gain. Using fresh OP in lamb feed resulted in a 30% increase in these key metrics, making it a promising option for livestock farmers looking to optimize their herd's growth and health. In the case of sheep supplemented with OP at doses of 300 to 600 g/animal/day, it did not influence the weights at birth, weaning, and pre-weaning gain (Ruiz-Hernández et al. 2019). Ruminants tolerate relatively high calcium and phosphorus levels if magnesium is not greater than 0.15% in the diet (Moyano-Tapia et al. 2020). Calcium absorption occurs in the rumen and through an active and passive process at the intestinal level that is mediated by vitamin D (Christakos et al. 2011). The levels of calcium and phosphorus in the animals' diet are reflected in the mineral profile of the blood tissue; for example, lambs with reproductive activity have 2.54 to 2.74 mmol l^{-1} levels in the blood serum, indicating a status of normocalcemic. A calcium level of less than 2.02 mmol l^{-1} in the blood serum indicates hypocalcemia (Stojković et al. 2014). Calcium needs depend on the physiological conditions of the animals, and the calcium content in the blood serum of the lambs and goats in this study indicates a status of normocalcemia. There were no significant differences (P>0.05) between the groups. The phosphorus content in all groups of females was 0.98 $mmol^{-1}$ serum on average. Physiological phosphorus levels were within the normal range with levels of 1.45 to 2.0 $mmol^{-1}$ (Hejcmanova et al. 2016).

CONCLUSIONS

The data show no differences in weight gain, feed intake, and conversion in lambs and goats fed the compared diets, including one with dry OP with a calcium source. Limestone facilitated the handling of OP and decreased the proliferation of flies. Natural oxidation of the bagasse due to exposure to air was avoided. It is evident that handling orange peels when they are dried outdoors and under sunlight involves more costs, and their handling is complicated during the year's seasons. Including 10% limestone was efficient and ideal for drying OP. The calcium content did not affect the health of the animals or alter their productive behavior, and it increased the hygienic benefits on the farm.

Author contributions

Conceptualization – DPD, JLPC, investigation – JERB, MFMG, methodology – RLC, AGV, formal analysis – RCL, JLPC, writing – original draft – JERB, RLC, writing – review & editing – JERB, AGV.

Conflicts of interest

The authors declare no potential conflicts of interest.

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