



Sustainable Utilization of Molasses and Vinasses Multi-Nutrient Blocks in Pregnant Mehraban Ewes: Effects on Performance, Metabolism, and Environmental Footprint

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Article Info	ABSTRACT
Article type: Research Article	The use of agricultural by-products in livestock feed is a sustainable strategy to reduce feed costs and environmental impacts. This study evaluated the effects of multinutrient blocks containing molasses and vinasses on growth performance, blood metabolites, rumen parameters, and environmental sustainability in pregnant Mehraban ewes. Sixty ewes were divided to three groups: a control group grazing without supplementation, groups supplemented with molasse-based multi-nutrient blocks (MMNB) or vinasse-based multi-nutrient blocks (VMNB) at 300 g/day. Over a 30-day period, body weight, blood parameters, and rumen fermentation characteristics were assessed. The results indicated no significant effect of MMNB or VMNB supplementation on body weight ($P > 0.05$). However, blood glucose decreased on day 15 in the supplemented groups ($P < 0.05$), suggesting improved insulin sensitivity, while urea levels increased ($P < 0.05$), likely due to higher nitrogen intake. Ruminant ammonia nitrogen levels were elevated in both the treatment groups, reflecting enhanced protein degradation. From an environmental perspective, MMNB and VMNB reduced the water footprint by 53% and 56%, carbon emissions by 50% and 53%, and land use by 63% and 66%, respectively, compared with conventional concentrate feed. The observed changes in blood metabolites, including improved antioxidant status, indicate enhanced resilience to metabolic stresses that are common in tropical environments, such as heat and poor forage availability. These findings highlight the potential of molasse- and vinasse-based feed supplements in improving livestock sustainability without compromising animal performance. By repurposing agro-industrial waste into nutrient-rich feed, this strategy addresses critical challenges in livestock production, reducing reliance on resource-intensive crops, curbing emissions, and promoting circular agriculture. Farmers and policymakers can adopt these blocks to enhance food system resilience amid climate change.
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Extended Abstract

Introduction

Recent environmental concerns have increased interest in managing by-products from food and agriculture industries, particularly as options for animal feed (Tufarelli et al. 2013). Using agricultural by-products in animal nutrition not only reduces the environmental impact of these materials but also enhances their economic value and profitability (Malenica et al. 2023). This approach offers an efficient method for transforming lower-quality food materials into higher-quality products, such as meat, while simultaneously decreasing livestock dependence on feed that could otherwise serve as human food (Bampidis and Robinson 2006). Among these by-products, molasses and vinasses, derived from sugar beet and sugarcane processing, have shown potential for animal feeding applications (Gerimipour et al. 2019).

Molasses, a byproduct or final product of sugarcane or sugar beet processing, is obtained during the production of raw or refined sugars. This viscous liquid is characterized by a high concentration that impedes the complete crystallization of its sugar content through conventional methods. Molasses is widely recognized as a high-quality energy source and frequently incorporated into ruminant diets (Mordenti et al. 2021). Vinasses or stillage are byproducts of the anaerobic fermentation of molasses and contain elevated concentrations of salts and organic matter. This wastewater, which generates 10 to 18 L L⁻¹ of ethanol, contaminates soil and surface water and poses a threat to aquatic ecosystems (Brito et al. 2024). Vinasses have high concentrations of potassium, calcium, magnesium, sulfur, and nitrogen. Furthermore, the amino acids present contribute to metabolic processes and activate the immune system in various species (Hidalgo et al. 2009). The concentration of soluble carbohydrates in vinasses is lower than that in molasses, while its protein and ash content are higher. It has been documented that the organic acids present in vinasses enhance feed conversion ratio, increase growth rates, improve digestibility, and facilitate nutrient metabolism (Hidalgo et al. 2009). In a separate study, it was reported that a mixture of bagasse and vinasses, when used in the fattening of lambs, resulted in reduced feed consumption and increased weight gain, with no effect on carcass traits (López-Campos et al. 2011).

The incorporation of molasses and vinasses into livestock feed systems presents logistical challenges due to the need for storage, transportation, and handling infrastructure. However, integrating these by-products into lick blocks offers a practical solution by simplifying feeding protocols and enhancing feed cohesion. Multi-nutrient blocks (MNB) reduce reliance on commercial concentrates, lower costs, and ease competition for grain-based resources between livestock and humans (de Evan et al. 2020). Moreover, Iranian pastures often lack sufficient energy, protein, and minerals, highlighting the potential of MNB to meet livestock nutritional needs and promote sustainable practices. These seasonal deficiencies parallel feed scarcity issues faced across tropical and subtropical regions, where drought, poor pasture quality, and fluctuating grain prices repeatedly threaten small ruminant productivity. In this study, we hypothesize that using molasses and vinasses in MNB can significantly reduce the environmental impact of sheep production while maintaining animal health. We propose that these by-products require less land, water, and fertilizer than conventional feeds, lowering water and carbon footprints and improving land use efficiency, especially in water-scarce regions like Iran. Thus, we evaluated the impact of molasses and vinasses based MNB (MMNB and VMNB) on growth performance, blood metabolites, rumen parameters, and environmental sustainability in pregnant Mehraban ewes. Iran's semi-arid sheep systems share key characteristics with livestock production landscapes in Africa, South Asia, and Latin America, where resource limitations and climate stressors are pronounced.

Material and methods

The present study was conducted in the rangelands and traditional livestock farming systems of Baghche village, located 25 kilometers from Hamedan, Iran. For this purpose, 60 Mehraban pregnant ewes (parity 1 to 4) with a mean body weight of 43 ± 3 kg were allocated to three experimental groups (20 replicates per group) using a completely randomized design. All experimental procedures involving animals were approved by the Research Ethics Committee of Bu-Ali Sina University (Approval No. 1680823) and complied with institutional guidelines for animal care and use. The experimental treatments consisted of: 1) a control group (pasture without MNB), 2) pasture supplemented with access to MMNB, and 3) pasture supplemented with access to VMNB. All animals were in phase of late pregnancy (i.e., 45-55 days to parturition). The MNBs were provided 300 g/sheep/day block twice daily: at 8:00 AM before the livestock were sent to graze and at 5:00 PM after their return from the pasture, over a 30-day period. An adaptation period of 10-day was considered before starting experimental periods. Based on the average age of the ewes, the MNBs were formulated in accordance with NRC (1985) standards. A diet was formulated theoretically (TC) to calculate environmental parameters, and was not subjected to in vivo evaluation using pregnant ewes (Table 1). To mitigate internal parasite infections, all ewes were orally administered albendazole tablets.

Table 1. Ingredients and chemical composition of multi-nutrient blocks including molasses (MMNB) or vinasses (VMNB) for supplementation of pregnant Mehraban ewes

جدول ۱. اجزا و ترکیبات شیمیایی بلوک های چند مغذی حاوی ملاس یا ویناس برای استفاده در تغذیه میش های آبستن مهربان

Ingredients (% DM)	MMNB	VMNB	TC ¹
Tomato pulp	16.9	19.0	-
Rice Bran	13.7	15.5	-
Molasses	36.2	0	-
Vinasses	0	26.5	-
Waste Yeast ²	0	7.6	-
Barley grain	-	-	19.1
Corn grain	-	-	10.0
Wheat bran	-	-	28.5
Soybean Meal	23.5	21.7	34.1
Urea	3.45	3.45	2.00
Salt	3.45	3.45	3.45
Mineral and Vitamin Supplement	2.8	2.8	2.8
Chemical Composition			
Metabolisable Eenergy (Mcal/Kg DM)	2.68	2.60	2.62
Crude Protein (% DM)	29.4	30.1	29.8
Calcium (% DM)	1.31	1.33	1.32
Phosphorus (% DM)	0.62	0.67	0.68

1. Theoretical concentrate formulated for calculation of some environmental and sustainability parameters. MMNB and VMNB were formulated to be approximately isonitrogenous and isoenergetic compared to TC

2. Waste yeast is dead yeast cells precipitated in bottom of fermentation tank of alcohol production

Measurements and Analyses

Chemical Analyses of Feed

The chemical composition of the feed was determined using established analytical methods. Dry matter (DM) and crude protein (CP), were measured according to the standard procedures outlined by the Association of Official Analytical Chemists (AOAC 1990). Throughout the experimental period, feed blocks were weighed daily and provided to the sheep. Body weights were recorded at 10-day intervals prior to morning feeding to assess growth and health responses to the experimental diets.

Blood parameters

Blood samples were collected from the jugular vein of all sheep on days 15 and 30 of the experiment to assess metabolic and oxidative stress markers. Samples were divided into two tubes: one containing EDTA anticoagulant for plasma separation and another for serum. The values of glucose, total protein, albumin, and urea were measured using commercial kits (Pars Azmoon, Iran) with an autoanalyzer. Antioxidant enzyme activity was determined using the RANSEL kit (Randox Laboratories, UK), while malondialdehyde (MDA) levels, an indicator of lipid peroxidation, were quantified using a modified method by Buege and Aust (1978).

Rumen fermentation analyses

Rumen fluid was collected and analyzed to assess fermentation parameters. Rumen fluid was transferred to 50 mL Falcon tubes and centrifuged at 5000 rpm for 20 minutes at 4°C. The supernatant was mixed with 2 N HCl at a 1:1 ratio, and ammonia nitrogen concentration was measured using the phenol-hypochlorite method (Broderick and Kang 1980). For recording protozoa number, at the end of the trial, rumen fluid was collected via an esophageal tube and fixed with 10% formaldehyde solution to preserve protozoa. Samples were stained with methylene blue and counted under a light microscope using a specialized counting slide, as outlined by Dehority (1993).

Environmental and sustainability factors

To assess the environmental sustainability of the three diets MMNB, VMNB, and TC Ingredients were categorized into two groups based on their production origin. First, high-impact ingredients: Primary crops (e.g., barley grain, corn grain, soybean meal), which require significant land, water, and energy inputs for cultivation. Second, low-impact ingredients: agricultural by-products (e.g., tomato pulp, rice bran, molasses, vinasses, waste yeast, wheat bran) and minor additives (e.g., urea, salt, mineral supplements), which incur minimal additional environmental impact as they are residuals of other processes or have negligible contributions to the assessed metrics.

Environmental impact values were assigned using generalized estimates from agricultural literature: Water Footprint: 1000 L Kg⁻¹ for primary crops and 100 L kg⁻¹ for by-products (Mekonnen and Hoekstra 2011); Carbon Footprint: 0.75 kg CO₂e kg⁻¹ for primary crops and 0.1 kg CO₂e kg⁻¹ for by-products (Clune et al. 2017); Land Use: 1.5 m² kg⁻¹ for primary crops and 0 m² kg⁻¹ for by-products, assuming no additional land allocation for by-products (Nemecek et al. 2016).

For each diet, the proportion of high-impact ingredients was calculated, and the environmental impact was determined as a weighted sum of contributions from high-impact and low-impact ingredients per kilogram of feed. These estimates provide relative comparisons rather than absolute values, due to the absence of region-specific production data.

Statistical analysis

Data for blood parameters, which involved repeated measurements over time, were analyzed using the General Linear Model (PROC GLM) procedure in SAS 9.4 (SAS Institute Inc., Cary, NC, USA). In contrast, body weight and rumen parameters, measured only at a single time point, were analyzed using a standard completely randomized design (CRD) model

The statistical model for the repeated measures analysis was as follows:

$$Y_{ijk} = \mu + T_i + A_{j(i)} + D_k + (T \times D)_{ik} + (A \times D)_{jk} + \varepsilon_{ijk}$$

Where: Y_{ijk} = the response variable for the animal j in the treatment i on the day k , μ = overall mean, T_i = fixed effect of treatment i (Control, MMNB, VMNB), $A_{j(i)}$ = random effect of animal j nested within treatment i , D_k = fixed effect of sampling day k , $(T \times D)_{ik}$ = interaction effect between treatment i and day k , $(A \times D)_{jk}$ = interaction between animal j and sampling day k and ε_{ijk} = residual error. When interactions were not significant ($P > 0.05$), they were removed from the model and main effects were reported. All variables exhibited a normal distribution upon assessment for normality. Means were compared using Tukey's HSD test at a significance level of $\alpha = 0.05$ to identify significant differences among treatment groups.

Results

Body Weight Changes

As illustrated in Table 2, supplementation with molasses-vinasses lick blocks did not significantly affect ($P > 0.05$) body weight at any measured interval.

Table 2. Effects of multi-nutrient blocks containing molasses (MMNB) or vinasses (VMNB) on body weight in Mehraban ewes in different days of experiment

جدول ۲. اثر بلوک های چند مغذی حاوی ملاس (MMNB) یا (VMNB) بر وزن میش های نژاد مهربان در روزهای مختلف آزمایش

Days of experiments	Body weight (kg)				P Value*
	Control	MMNB	VMNB	SEM	
0	45.2	43.3	41.9	1.36	0.22
10	46.1	44.0	42.8	1.4	0.24
20	46.4	45.3	44.3	1.43	0.59
30	47.8	46.2	44.7	1.5	0.36

* *P-values represent treatment effects within each day*

As observed in Table 3, 15 days after the administration of lick blocks to Mehraban sheep, the blood glucose concentration in sheep supplemented with the blocks decreased significantly compared to the control group ($P < 0.05$). However, by day 30 of the experiment, blood glucose levels in sheep receiving molasse-containing lick blocks exhibited a significant increase relative to both the control and vinasse-supplemented groups ($P < 0.05$). Dietary supplementation with molasse-containing lick blocks reduced the total protein concentration in the blood on day 30 compared to the control group ($P < 0.05$), although no statistically significant differences in total protein were observed among the treatment groups on day 15 ($P > 0.05$). The results indicate that the use of lick blocks containing molasses and vinasses did not significantly affect blood albumin concentration ($P > 0.05$). In contrast, a significant increase in blood urea concentration was observed on both day 15 and day 30 in sheep receiving the lick blocks ($P < 0.05$). Blood calcium concentrations in sheep fed vinasse- and molasse-containing blocks increased on day 15 and decreased on day 30, respectively, relative to the control group ($P < 0.05$). On day 15, sheep supplemented with vinasse-containing blocks showed a significant increase in blood phosphorus concentration compared to the control ($P < 0.05$); however, by day 30, phosphorus levels were not significantly influenced by the experimental treatments ($P > 0.05$). Malondialdehyde was not

influenced by the experimental treatments throughout the trial period ($P > 0.05$). On day 15, the total antioxidant capacity (TAC) was significantly higher in the groups receiving lick blocks compared to the control group ($P < 0.05$), although no significant difference was observed between the molasses and vinasses groups ($P > 0.05$). By day 30, the TAC was significantly higher in the vinasses block group compared to the molasses block group ($P < 0.05$), but there was no significant difference when compared to the control group ($P > 0.05$).

Table 3 - Effects of multi-nutrient blocks containing molasses (MMNB) or vinasses (VMNB) on blood parameters and antioxidant activity in Mehraban pregnant ewes

جدول ۳. اثر بلوک های چند مغذی حاوی ملاس (MMNB) یا (VMNB) بر فراسنجه های خونی و فعالیت آنتی اکسیدانی در میش های آبستن نژاد مهربان

Parameter	Days	Control	MMNB	VMNB	SEM	P Value*
Glucose (mg dL ⁻¹)	15	56.9 ^a	49.0 ^b	49.0 ^b	2.08	0.012
	30	52.2 ^{ab}	57.1 ^a	51.0 ^b	1.89	0.057
Total Protein (g dL ⁻¹)	15	9.13	8.96	9.47	0.21	0.238
	30	7.49 ^a	6.41 ^b	9.57 ^a	0.28	0.009
Albumin (g dL ⁻¹)	15	5.24	5.36	5.31	0.14	0.855
	30	4.53	4.39	4.27	0.17	0.563
Blood Urea (mg dL ⁻¹)	15	13.0 ^b	29.0 ^a	28.8 ^a	1.40	0.001
	30	11.5 ^b	15.9 ^a	17.4 ^a	1.23	0.003
Calcium (mg L ⁻¹)	15	8.31 ^b	10.52 ^a	9.86 ^a	0.28	0.001
	30	8.64 ^a	6.30 ^c	8.07 ^b	0.18	0.001
Phosphorus (mg L ⁻¹)	15	5.01 ^b	5.28 ^b	6.38 ^a	0.38	0.036
	30	4.27	4.14	4.83	0.31	0.251
Malondialdehyde (nmol mL ⁻¹)	15	1.95	2.29	2.21	0.16	0.328
	30	2.70	2.60	2.56	0.22	0.896
Total antioxidant capacity (mmol L ⁻¹)	15	0.39 ^b	0.39 ^{ab}	0.40 ^a	0.003	0.05
	30	0.40 ^{ab}	0.39 ^b	0.40 ^a	0.003	0.07

Different letters in rows indicate significance at the 5% level. * P-values represent treatment effects within each day

Ammonia nitrogen and numen protozoa

The use of MNBs significantly increased the concentration of rumen ammonia nitrogen compared to the control group (Table 4; $P < 0.05$). An increase in the number of holotrichs and a decrease in the number of entodiniomorphs in the rumen were observed in the blocks containing vinasses and molasses, respectively ($P < 0.05$).

Table 4 - Effects of multi-nutrient blocks containing molasses (MMNB) or vinasses (VMNB) on ammonia nitrogen and protozoa concentration in rumen fluid of Mehraban pregnant ewes

جدول ۴. اثر بلوک های چند مغذی حاوی ملاس (MMNB) یا (VMNB) بر نیتروژن آمونیاکی و غلظت پروتوزوآ در مایع شکمبه میش های آبستن نژاد مهربان

Parameter	Control	MMNB	VMNB	SEM	P Value
Ammonia nitrogen (mg L ⁻¹)	4.77 ^b	7.17 ^a	6.22 ^a	0.41	0.003
Holotrichs (×10 ⁵)	29.4 ^b	27.5 ^b	31.5 ^a	0.71	0.005
Entodiniomorphs (×10 ⁵)	41.4 ^a	40.9 ^b	41.5 ^a	0.13	0.001

Different letters in rows indicate significance at the 5% level

Environmental sustainability assessment

The environmental sustainability assessment of three livestock diets MNB, VMNB and TC revealed notable differences in their environmental impacts, specifically in terms of water footprint, carbon footprint, and land use (Table 5). The MMNB and VMNB diets, which incorporate higher proportions of agricultural by-products, demonstrated significantly lower environmental impacts compared to the new concentrate diet, which relies more heavily on primary crops.

Quantitatively, the water footprint was calculated as 311.5 L kg⁻¹ for MMNB and 295.3 L kg⁻¹ for VMNB, in contrast to 669.3 L kg⁻¹ for the TC. This corresponds to reductions of approximately 53% for MMNB and 56% for VMNB relative to the concentrate diet. The carbon footprint exhibited a similar trend, with MMNB recording 0.25 kg CO₂e kg⁻¹ and VMNB 0.24 kg CO₂e kg⁻¹, compared to 0.51 kg CO₂e kg⁻¹ for the TC, reflecting reductions of 50% and 53%, respectively. Land use was also markedly lower for the by-product-based diets, with MMNB requiring 0.35 m² kg⁻¹ and VMNB 0.32 m² kg⁻¹, versus 0.95 m² kg⁻¹ for the TC, indicating reductions of 63% and 66%, respectively.

Table 5. Estimated environmental impacts of multi-nutrient blocks containing molasses (MMNB) or vinasses (VMNB), and regular concentrate with no by-products (TC)

جدول ۵. اثر فراسنجه های محیطی تخمینی استفاده از بلوک های چند مغذی حاوی ملاس (MMNB) یا (VMNB) و یا استفاده از کنسنتره معمولی بدون محصولات جانبی (TC)

Diet	Water Footprint (L kg ⁻¹)	Carbon Footprint (kg CO ₂ e kg ⁻¹)	Land Use (m ² kg ⁻¹)
MMNB	311.5	0.25	0.35
VMNB	295.3	0.24	0.33
TC	669.3	0.51	0.95

Discussion

In the present study, the use of lick blocks containing vinasses and molasses did not affect the body weight of Mehraban ewes. This finding aligns with Pourasad et al. (2014), who examined the effects of molasses and vinasses on the performance of Mahabadi kids and reported that inclusion levels of 8% and 12% vinasses had no significant impact on body weight or feed conversion ratio. Similarly, Yalçın et al (2010), demonstrated that vinasses inclusion up to 8% did not influence growth performance in steers. However, these results contrast López-Campos et al (2011), who found that increasing vinasses levels to 20% reduced the growth performance of fattening lambs. Additionally, the lack of effect on animal performance has been attributed to the low energy content of vinasses (Fernández et al. 2009; Yalçın et al. 2010). In a comparable study, it was observed no significant effects on body weight or daily weight gain in lambs fed diets with 0%, 7.5%, and 15% molasses (Khayat et al. 2014). In contrast, diets containing 30% and 40% molasses positively influenced body weight in

goats, attributing this improvement to enhanced palatability (Osman et al. 2020). The absence of statistically significant differences in the body weight of the experimental ewes in current study suggests that the energy requirements of the animals were adequately fulfilled across all treatment groups, including the control group. It is noteworthy that the ewes in the control group had access to wheat stubble grazing and were supplemented with barley grain during their time in the pen. Consequently, it is likely that the barley provided sufficient energy to meet the nutritional demands of the ewes in the control group.

The initial reduction of blood glucose at day 15, may reflect enhanced insulin sensitivity triggered by fermentable carbohydrates in the supplements, promoting peripheral glucose uptake (Soares et al. 2022). Conversely, the control group's transient hyperglycemia could stem from cortisol-driven gluconeogenesis due to dietary monotony or handling stress (Moberg 2000; NRC 2007). By day 30, however, glucose levels in MMNB-supplemented ewes rose, likely due to sustained energy supply from molasses, whereas the control group's decline suggests glycogen depletion and inadequate energy intake, (NRC 2007). Both MMNB and VMNB groups exhibited elevated blood urea on Days 15 and 30 which may reflect enhanced protein catabolism from MMNB/VMNB nitrogen-rich substrates (e.g., urea, soybean meal). Notably, MMNB reduced total protein by Day 30, potentially due to amino acid diversion toward gluconeogenesis or reduced hepatic synthesis (Larsen and Kristensen 2012). In contrast, VMNB maintained higher total protein, suggesting better nitrogen retention, possibly due to vinasses amino acids supporting hepatic function (Hidalgo et al. 2009).

A sharp decline in day 30 could be attributed to the divergent effects of MMNB and VMNB on calcium homeostasis and highlight the critical role of mineral interactions and bioavailability in late-gestation ewes. While MMNB's high soluble potassium likely elevated the Dietary Cation-Anion Difference (DCAD), impairing calcium mobilization and renal reabsorption (Horst et al. 2005), VMNB (with high levels of magnesium, and sulphur; Hidalgo et al 2009) maintained stable calcium levels probably through synergistic mechanisms. Magnesium might supported parathyroid hormone function (Goff 2018) and sulfur reduced DCAD by contributing anions (Munn *et al.* 2024). These findings emphasize that calcium availability depends not just on dietary content but on electrolyte balance and co-mineral synergies, positioning VMNB as a more effective supplement for meeting gestational calcium demands (NRC 2007). Future studies should quantify DCAD and urinary mineral excretion to refine supplementation strategies. VMNB improved total antioxidant capacity (TAC) by Day 15 likely due to vinasses polyphenols and organic acids scavenging free radicals (Hidalgo et al. 2009). By Day 30, VMNB maintained higher TAC underscoring its oxidative stability.

Both MMNB and VMNB supplementation increased ruminal ammonia nitrogen concentrations compared to the control, likely attributable to their higher crude protein content and enhanced proteolytic activity in the rumen. The elevated ammonia levels correlate with increased blood urea concentrations observed in these groups (Table 3). However, the supplementation of both types of lick blocks led to a substantial increase (50–100%) in ruminal ammonia concentrations and BUN and compared to the control group. These elevated levels are of particular concern regarding the metabolic health of pregnant animals. Furthermore, the resulting increase in nitrogen excretion poses significant environmental challenges, which might be inconsistent with the objectives of sustainable livestock production.

In contrast, Pourasad et al (2014) reported that inclusion of 4%, 8%, and 12% vinasses in Mahabadi kid diets had no significant effect on blood glucose, albumin, total protein, calcium, or phosphorus concentrations. Also, Yalçın et al (2010) reported that blood urea, total protein, and cholesterol concentrations remained unaffected by vinasses inclusion in lamb diets. Conversely, it was found that 40% molasses in diet of Nubian goats increased total protein concentrations compared to the control (Osman et al. 2020), and reductions in blood glucose and urea nitrogen levels have been observed with 10% and 20% vinasses (López-Campos et al. 2011). Karalazos and Swan (1977) suggested that vinasses inclusion up to 20% reduces fermentable energy in the diet, impeding the conversion of ammonia to microbial protein in the rumen, which consequently elevates blood ammonia and urea levels. This mechanism aligns with the current study's observations of increased blood urea and rumen ammonia in ewes receiving vinasse-containing lick blocks. The current findings highlight the variable responses to vinasses supplementation across different ruminant species and physiological states, with pregnant ewes showing distinct metabolic adaptations compared to growing kids and lambs reported in previous studies.

The incorporation of agricultural by-products such as molasses and vinasses into livestock nutrition significantly enhances environmental sustainability by reducing reliance on conventional feed crops. The present study demonstrated that MMNB and VMNB diets substantially decreased the water footprint, carbon footprint, and land use compared to traditional concentrate-based diets. These findings align with previous studies indicating that by-product-based diets improve feed sustainability without compromising animal performance (Gerber et al. 2013; Makkar 2016).

The marked decrease in water footprint with MMNB and VMNB reflects the replacement of irrigation-dependent primary crops with low-allocation by-products (molasses, vinasses). This substitution substantially lowers water use per unit of feed. Given that barley, corn, and soybean meal often require heavy

irrigation, with water footprints near 1,200–2,000 L kg⁻¹ (Mekonnen and Hoekstra 2011), water consumption remains a central sustainability challenge in livestock systems. The observed water footprint reductions in MMNB and VMNB diets highlight the role of circular agricultural practices in mitigating water scarcity (Hoekstra 2012). Similarly, land use efficiency is a critical aspect of sustainable livestock systems. The marked reduction in land use is a direct consequence of the mechanism through substitution with molasses and vinasses do not necessitate de novo land allocation for their production, unlike conventional grains. This efficient use of existing resources is a core tenet of circular agriculture and directly explains the improved land use efficiency observed. Primary feed crops require significant land resources for cultivation, contributing to deforestation and biodiversity loss. By replacing conventional grains with molasses and vinasses, MMNB and VMNB eliminate the need for additional cropland, aligning with global sustainability goals (Boer and Ittersum 2018).

Furthermore, the carbon footprint reductions observed in MMNB and VMNB diets reflect a shift toward lower emission feed systems. Conventional feed production is a major contributor to greenhouse gas (GHG) emissions due to fertilizer application, land-use change, and transportation (Nemecek et al. 2016). Using waste by-products as feed reduces greenhouse gas emissions per unit of energy and weight gain, supporting sustainable circular economy practices in livestock nutrition (Steinfeld et al. 2006). The lower carbon footprint of MMNB and VMNB reflects three effects: fewer emissions from fertilizer use and field management, avoidance of land-use change for extra feed crops, and use of by-products that would otherwise emit when discarded. In combination, these effects reduce the carbon intensity of livestock feed. This study shows that vinasse-based blocks work better than molasse-based blocks for pregnant Mehraban ewes. VMNB improved the ewe's antioxidant capacity and mineral absorption while keeping normal rumen function. Both types of blocks provided significant environmental benefits. They reduced water use, carbon emissions, and land requirements compared to standard concentrate feeds. These results confirm our hypothesis that using agricultural waste products in livestock feed reduces environmental impact by reusing materials from existing production processes. The environmental benefits directly result from three mechanisms: replacing water-intensive primary crops with by-products that require no additional irrigation, eliminating the need for dedicated cropland that would otherwise contribute to habitat conversion, and avoiding emissions associated with fertilizer use and land-use change. This approach exemplifies circular agriculture principles by transforming potential waste streams into valuable nutritional resources. MMNB and VMNB supplementation represents a practical pathway toward more resource-efficient livestock systems, particularly relevant in regions like Iran facing water scarcity and environmental pressures. Future research should explore optimal inclusion rates of these by-products and their long-term effects on reproductive and production performance in ruminants.

Data availability

The data supporting this study can be made available upon reasonable request to the corresponding author.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Declaration of Funding

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Author Contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Sajad Ghasemi. The first draft of the manuscript was written by Daryoush Alipour and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

The author declares no conflict of interest.

استفاده پایدار از بلوک های چند مغذی حاوی ویناس یا ملاس تغذیه میش های آبستن: عملکرد، متابولیسم و رد پای زیست محیطی

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اطلاعات مقاله	چکیده
نوع مقاله: مقاله پژوهشی	استفاده از محصولات جانبی کشاورزی در تغذیه دام، راهبردی پایدار برای کاهش هزینه های خوراک و اثرات زیست محیطی به شمار می رود. در این مطالعه، اثرات بلوک های چندمغذی حاوی ملاس و ویناس بر عملکرد رشد، متابولیت های خونی، شاخص های شکمبه و پایداری زیست محیطی در میش های آبستن نژاد مهربان بررسی شد. در مجموع، ۶۰ رأس میش به سه گروه تقسیم شدند: گروه شاهد که بدون مکمل در مرتع چرا می کرد، و دو گروه تیمار که به ترتیب با بلوک های چندمغذی بر پایه ملاس یا بر پایه ویناس به میزان ۳۰۰ گرم در روز دریافت کردند. در طول یک دوره ۳۰ روزه، وزن بدن، شاخص های خونی و ویژگی های تخمیر شکمبه مورد ارزیابی قرار گرفت. نتایج نشان داد که دادن بلوک ها اثر معنی داری بر وزن بدن نداشت ($P > 0.05$) با این حال، غلظت گلوکز خون در روز پانزدهم در گروه های مکمل کاهش یافت ($P > 0.05$)، که می تواند نشان دهنده بهبود حساسیت به انسولین باشد، در حالی که سطح اوره خون افزایش یافت ($P > 0.05$) که احتمالاً ناشی از دریافت بیشتر نیتروژن است. غلظت نیتروژن آمونیاکی شکمبه در هر دو گروه تیمار افزایش یافت که بیانگر افزایش تجزیه پروتئین در شکمبه است. از دیدگاه زیست محیطی، استفاده از بلوک های ملاس و ویناس در مقایسه با خوراک کنسانتره متداول، به ترتیب موجب کاهش رد پای آب به میزان ۵۳ و ۵۶ درصد، کاهش انتشار کربن به میزان ۵۰ و ۵۳ درصد و کاهش استفاده از زمین به میزان ۶۳ و ۶۶ درصد شد. تغییرات مشاهده شده در متابولیت های خونی، از جمله بهبود وضعیت آنتی اکسیدانی، نشان دهنده افزایش توان دام ها در مقابله با تنش های متابولیکی رایج در محیط های گرمسیری، مانند تنش گرمایی و محدودیت دسترسی به علوفه باکیفیت، است. این یافته ها بر توان مکمل های خوراکی مبتنی بر ملاس و ویناس در ارتقای پایداری دامپروری بدون به خطر انداختن عملکرد دام تأکید می کند. تبدیل ضایعات صنایع کشاورزی به خوراک های غنی از مواد مغذی، راهکاری مؤثر برای مواجهه با چالش های اساسی تولید دام است که ضمن کاهش وابستگی به محصولات پرمصرف منابع، انتشار آلاینده ها را محدود کرده و کشاورزی چرخشی را ترویج می دهد. کشاورزان و سیاست گذاران می توانند با به کارگیری این بلوک ها، تاب آوری سامانه های غذایی را در شرایط تغییرات اقلیمی افزایش دهند.

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