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Research Article

Physico-Chemical Characteristics and In Vitro Rumen Degradability of Insect Frass as NPN Source for Mineral Blocks in Goats

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ABSTRACT

The study was conducted to determine the potential of superworm (*Zophobas morio*) larvae (SWL) and black soldier fly (*Hermetia illucens*) larvae (BSFL) frass at 10% inclusion as non-protein nitrogen (NPN) source in formulating mineral blocks for goats, with emphasis on the physico-chemical properties of the mineral blocks, and to assess the extent of feed degradation in goats supplemented with insect frass-based mineral block through an *in vitro* degradability trial. A total of 16 post-weaned goats were used to determine the effects of supplementing insect frass-based mineral blocks on the feed degradation in goats. The goats were arranged in a randomized complete block design (RCBD) with four (4) treatments and four (4) blocks with initial body weight (BW) as the blocking factor. Treatment A (control), Treatment B (urea molasses mineral block) (UMMB), Treatment C (superworm larvae frass mineral block) (SWLFMB), and Treatment D (black soldier fly larvae frass mineral block) (BSFLFMB) served as treatments. Based on the results, insect frass-based mineral blocks showed potential as a good nutritional supplement for goats. These mineral blocks offer valuable sources of protein, non-protein nitrogen (NPN), and minerals. Evaluation of hardness and solubility indicated that the SWLFMB showed better hardness and compactness, but demonstrated the highest solubility among formulations. In contrast, the UMMB displayed relatively low hardness and compactness, yet was the least soluble of all the mineral block variants. Moreover, *in vitro* studies showed no significant difference among treatments. Therefore, insect frass-based mineral blocks are a viable alternative source of minerals and NPN for goats, which can be utilized to optimize ruminant feed resources.

Keywords: *Black soldier fly, Insect frass, in vitro, Goats, Mineral block, NPN source, Superworm*

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Introduction

The scarcity of good quality forages is one of the major problems encountered by goat raisers in the country, which hinders the farmer’s ability to provide ruminants with their daily nutrient requirements (Liang & Paengkoum 2019). Moreover, goat raisers in the Philippines are still practicing traditional farming systems (low-cost inputs) with no supplementation of either concentrate feeds or mineral blocks resulting in poor nutrition management, and herd management (Orden et al 2023). Consequently, this leads to a slow growth rate, high mortality rate, occurrence of diseases, low reproduction, and slow income generation for farmers (Loresco et al 2020). Finding alternative inexpensive protein and non-protein nitrogen (NPN) sources for ruminants could be the key to improvement of the goat nutrition.

Insects have been gaining popularity recently due to their rich nutritional composition. According to Roffeis et al (2018), insects have a good amount of nutrients which makes them a great alternative protein source in animal feed. Insects are highly prolific with a short life cycle. Its frass, a waste product of insect rearing is proven to contain an adequate amount of nutrients that could be utilized for animal consumption. Despite the potential of insect frass as a sustainable nitrogen (N) source in ruminant nutrition, limited research has investigated its efficacy when incorporated into a mineral block formulation for goats. Specifically, there is a lack of empirical data on how insect frass supplementation affects rumen fermentation, and nutrient digestibility in goats. This gap hinders our understanding of its role in addressing nitrogen deficiencies in forage-based diets and its potential economic benefits for smallholder farmers.

This study aims to evaluate the potential of superworm (*Zophobas morio*) and black soldier

fly (*Hermetia illucens*) larvae frass as N sources in mineral blocks for goats. It specifically focuses on analyzing the frass and mineral block composition, examining the physical properties of the mineral blocks, and determining the extent of feed degradability in goats supplemented with insect frass-based mineral blocks.

Materials and Methods

Animal Research Ethics

All animal procedures were conducted in accordance with the guidelines and regulations approved by the Institutional Animal Care and Use Committee (IACUC).

Insect Rearing and Harvesting of Frass

Adult insects of black soldier fly (BSF) and superworm (SW) were reared in an insect rearing facility with provision of space for laying and hatchment of larvae. The larvae were given rice bran and coconut pulp with a ratio of 1:3 as their substrate. Insect frass were collected from the larvae litter through sieving and was stored in a container. The frass was then dried and added to the mineral block formulation as a source of nitrogen for goats.

Preparation of Mineral Block

Table 1 shows the formulation of the mineral block. The number of ingredients mixed and the drying process was based on the urea molasses mineral block (UMMB) formulation and procedure by Yami (2007) with modification by replacing urea with either BSFL or SWL frass. All the ingredients were weighed accordingly to prepare a 3kg mineral block. The semi-solid mixture was poured into a wooden mold (13 cm x 13 cm x 10 cm) lined with plastic. Once molded, the blocks were sun-dried until constant weight and placed on a wooden slab at an air temperature of about 30 °C and humidity of about 70%.

Table 1. Ingredient composition (g/100g DM) of the molasses multi-nutrient block

INGREDIENTS	%	(g)
Bran	31	930
Molasses	30	900
NPN Source (Urea / frass)	10	300
Salt	4	120

INGREDIENTS	%	(g)
Lime	4	120
Cement	15	450
Monocalcium phosphate (MDCP)	5	150
Vit. & Mineral premix	1	30
TOTAL	100	3000

Experimental Design

Sixteen (16) post-weaned goats were randomly allocated to four (4) treatments receiving mineral blocks as described below. The experiment was laid out in a Randomized Complete Block Design (RCBD) with four (4) blocks based on the initial body weight (BW) of goats. Napier grass served as the basal diet for the animals and was given ad libitum with supplementation of concentrate feeds and kakawate (*Gliricidia sepium*) at 100 g/animal/day. Each goat was housed in an individual stall and was provided with clean water at all times. The following treatments served as supplements for the animals for 14 weeks; Treatment A (Control), Treatment B (Mineral block with urea as NPN) Treatment C (Mineral block with SWL frass as NPN), and Treatment D (Mineral block with BSFL frass as NPN).

Data Analysis

The data in *in vitro* degradability was run in Analysis of Variance (ANOVA) in RCBD using General Linear Model of Statistical Analysis System (SAS 9.4 M8). Treatment means were compared using Tukey's HSD and significant difference were declared at $p < 0.05$.

Proximate and Mineral Analysis of Insect Frass and Mineral Blocks

Both the insect frass and formulated mineral blocks were analyzed in three replicates using conventional methods for dry matter (DM), crude protein (CP), ether extract (EE), and crude ash (AOAC 2006). On the other hand, neutral detergent fiber (NDF) was assayed using Van Soest (1991) method. Gross energy (GE) of the samples were determined using IKA C1 Bomb Calorimeter Parr instrument (1L, USA). Lastly, frass and mineral block samples were sent to a laboratory for mineral analysis.

Hardness and Solubility of Mineral Blocks

The mineral blocks were assessed for hardness and compactness on the 21st day of drying with two (2) replicates per treatment. This was independently evaluated by several knowledgeable respondents, using a subjective scale: Soft (+), Medium (++), and Good (+++) as descriptions (Asaolu, 2012). Hardness was assessed by manually pressing the center of the block with a thumb, while solubility/stability was determined by soaking the well-dried mineral block samples in water for seven days (Adewumi, 2013). The rate of solubility was assessed by calculating the amount of mineral block dissolved and the percent solubility of the sample using the formula below.

$$\% \text{ Solubility} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times 100$$

In vitro Degradability Trial

Rumen fluid collection was conducted at the end of the feeding trial. The rumen fluid was filtered with five (5) layers of cheesecloth to remove digesta and excess bubbles in the fluid. Once filtered, the fluid was transferred into glass vials. Each treatment had three (3) replications. Each vial contained 20 mL of the rumen fluid, 10 mL of McDougall's buffer solution, and 3 grams of the forage sample. The vials were flushed with carbon dioxide (CO₂) and sealed with rubber caps to maintain the anaerobic condition before it was placed in the hot shaker bath for 48 hours at 38 °C – 40 °C. Then the residues were filtered with cheesecloth and were oven-dried for 48 hours at 55 – 65 °C until constant weight was observed (Kara, 2019). Thereafter, *in vitro* dry matter digestibility (IVDMD), *in vitro* organic matter digestibility (IVOMD), *in vitro* crude protein (IVCPD), and *in vitro* neutral detergent fiber digestibility (IVNDFD) were analyzed and each parameter had three (3) replications.

Results and Discussion

Chemical Composition of Insect Frass and Mineral Blocks

Table 2 presents the composition of SWL frass and BSFL frass. The result showed that SWL frass has higher DM (74.1%) than BSFL frass (39.8%) which may be influenced by the insect’s diet, its ability to digest organic materials, and the presence of chitin in the frass during molting (Dragojlovic et al 2022). Moreover, the DM content of SWL frass (74.1%) and BSFL frass (39.8%) was higher compared to the DM content of its larvae (Mattioli et al 2023 and Garttling & Schulz 2021). Meanwhile, the CP and EE results revealed that BSFL frass had the highest CP due to its higher N content, but had lower EE content compared to SWL frass (Lopes et al 2022 and Ainta et al 2023). The EE content of BSFL frass was lower (0.2%), while the CP (18.7%) was similar to the findings of Astuti and Wiryawan (2022), where frass of BSFL fed with palm oil meal medium contained 19% CP and 25%EE. While BSFL frass fed with organic waste medium had a CP content of around 15% and 21%EE.

The CP requirements of goats depend on the production stage and breed. Feed protein concentrate should be at 7-9% for maintenance, 15-18% from birth to weaning, 12-16% at growth stage, and 10-12% for finishing

(Gurung, 2020). The CP content of insect frass was lower than the required CP concentration for growth but was enough for the maintenance requirement of the animal. In terms of NDF content, BSFL frass had higher NDF (14.2%) than SWL frass (2.1%). The NDF content in frass may also be influenced by the ability of the insect to efficiently digest fibrous materials especially SWL which are known to have excellent digestion capabilities compared to other insects, and probably due to the chitin content in frass during insect molting.

Moreover, SWL frass had higher crude ash (1.7%) than BSFL frass (0.8%), while SWL frass had lower OM (98.3%) than BSFL frass (99.2%), respectively. This indicates that SWL frass had a higher mineral content than BSFL frass due to its higher ash content. Lastly, in terms of gross energy (GE), SWL frass has higher energy (4983 cal/g) than BSFL frass (4343 cal/g). This may be due to the lower NDF, higher DM, and slightly higher EE content in SWL than in BSFL because low fiber means more digestible, energy-dense components remain which contributes to higher GE values, and a higher DM means that the sample has less water and more solids (combustible) containing nutrients (fat, protein, fiber, carbohydrates) that contributes to GE.

Table 2. Mean Nutrient Composition of SWL frass and BSFL frass

COMPONENT	SWL Frass	BSFL Frass
Dry matter (%)	74.1	39.8
Crude protein (%)	17.6	18.7
Ether extract (%)	0.3	0.2
Neutral detergent fiber (%)	2.1	14.2
Crude ash (%)	1.7	0.8
Organic matter (%)	98.3	99.2
Gross energy (cal/g)	4983	4343

SWL – superworm larvae, BSFL – black soldier fly larvae

Table 3 shows the composition of mineral blocks with different NPN sources. The result implies that superworm larvae frass mineral block (SWLFMB) had the highest DM (74.1%), EE (3.2%), crude ash (98.6%), GE (2359.5 cal/g), and Ca (7.67%), respectively. Meanwhile, black soldier fly larvae frass mineral block (BSFLFMB) had the highest NDF (8.8%),

crude ash (98.6%), and P (1.85%). However, urea molasses mineral block (UMMB) had the highest CP (16.3%), and OM (1.6%).

According to Aksoy et al (2022), the composition of frass typically contains both true protein and non-protein nitrogen (NPN) sources, including uric acid, ammonia, and other microbial derivatives. The N component and OM in

insect frass were from a mix of exoskeleton (chitin), undigested substrate, microbial by-products, and insect excretions. The chemical composition of the mineral blocks including DM, NDF, EE, ash, and GE may be influenced by the type of N source present and the proportion of ingredients used in the formulation. Moreover, the higher CP content observed in UMMB may be attributed to the higher nitrogen con-

centration of urea compared to insect frass. Regarding the mineral composition, SWLFMB exhibited the highest calcium (Ca) content, while BSFLFMB had the highest phosphorus (P) content. In contrast, UMMB showed the lowest concentration of both Ca and P. These differences are likely reflective of the inherent mineral profiles of each type of nitrogen source used in the formulations.

Table 3. Composition of mineral blocks with different NPN source

COMPONENT	UMMB	SWLFMB	BSFLFMB
Dry matter (%)	54.1	56.9	52.9
Crude protein (%)	16.3	7.3	7.8
Ether extract (%)	0.7	0.7	0.9
Neutral detergent fiber (%)	3.1	5.4	8.8
Crude ash (%)	98.4	98.6	98.6
Organic matter (%)	1.6	1.4	1.4
Gross energy (cal/g)	2214.5	2359.5	2313.5
Calcium (%)	6.19	7.67	6.80
Phosphorous (%)	1.46	1.82	1.85

UMMB - urea molasses mineral block, SWLFMB - superworm larvae frass mineral block, BSFLFMB - black soldier fly larvae frass mineral block

Hardness and Solubility of Mineral Blocks

Table 4 shows the hardness and solubility of mineral blocks. A total of forty (40) respondents were asked to evaluate the hardness of the mineral blocks. Among the 40 respondents, 97.5% of respondents perceived the SWLFMB with good hardness, followed by BSFLFMB (82.5%), and UMMB (75.5%) with the lowest perception. In terms of solubility, SWLFMB showed the highest solubility at 37.3%, followed by BSFLFMB at 28.4%, and UMMB with the lowest solubility at 28.1%. For % solubility determination, the mineral blocks were submerged in water for seven (7) days to evaluate the percentage of the block's weight dissolved during the time of submersion. The solubility of mineral blocks is a critical parameter influencing their practical application in ruminant feeding.

Submerging the blocks in water simulated the prolonged exposure to moisture, such as in

the rumen or through salivation during licking. This method allowed for the determination of the percentage of the block's weight that dissolved over time, serving as an indicator of the nutrient release rate (Omoniyi et al 2013). The results suggest that SWLFMB, which had the highest solubility (37.3%), may offer quicker nutrient availability, potentially enhancing the immediate utilization of nitrogen and minerals. However, excessive solubility can also lead to faster depletion of the block, reducing its duration of use and potentially increasing supplementation costs. Conversely, UMMB with the lowest solubility (28.1%), may provide a slower, more sustained release, but could risk insufficient nutrient availability if dissolution is too limited. According to Upadhyay et al (2020), the daily consumption of mineral blocks in small ruminants should range from 60 – 125 per day.

Table 4. Hardness and solubility of mineral blocks (n = 40)

Criteria	UMMB	SWLFMB	BSFLFMB
Hardness			
Soft %	0	0	0
Medium %	25.00	2.50	17.50
Good %	75.00	97.50	82.50
Solubility (%)	28.10	37.30	28.40

UMMB - urea molasses mineral block, SWLFMB - superworm larvae frass mineral block, BSFLFMB - black soldier fly larvae frass mineral block

Moreover, urea when exposed to high humidity becomes highly hygroscopic (Eisa et al 2023) which may have affected the solubility and hardness of the UMMB. Insect frass, on the other hand, contained chitin from the insect’s exoskeleton which is a good natural binder ingredient that may contribute to the hardness of the insect frass-based mineral blocks (Triunfo et al 2021 and Kasprzak & Galiński 2023). In addition, results suggest that SWLFMB was the most soluble among mineral blocks. This may be due to the physical properties of the SWL frass itself such as its bulkiness, and bran-like texture which likely reduces the efficiency of the binder ingredient used in the formulation. Leading to a looser structure and increased susceptibility to water dissolution, compromising the block’s durability, that may result in faster consumption or wastage.

In vitro Degradability

Table 5 shows the *in vitro* degradability of Napier grass. Based on the result, *in vitro* feed degradability, *in vitro* crude protein degradability (IVCPD), *in vitro* dry matter degradability (IVDMD), *in vitro* neutral detergent fiber degradability (IVNDFD), *in vitro* acid detergent fiber degradability (IVADFD), *in vitro* crude ash degradability (IVCAD), and *in vitro* organic matter degradability (IVOMD) showed no significant difference across treatments. However, values showed that insect frass-based mineral block treatments had slightly higher nutrient degradation than the control. This suggests that frass-based mineral blocks (SWLFMB and BSFLFMB) had promising effects on the nutrient degradability in Napier grass, which could enhance its nutritive value for ruminants. Specifically, IVCPD was significantly enhanced, particularly by SWLFMB (79.9%), indicating

that these insect frass-based mineral blocks improve protein availability for rumen microbes. Moreover, IVNDFD and IVADFD showed improvements, especially with BSFLFMB and SWLFMB, suggesting potential benefits in fiber utilization. This may be due to the amount of mineral block consumed and the chemical composition of frass. Specifically, the protein and NPN content, which plays a critical role in rumen fermentation through its function in supporting microbial growth, protein synthesis, and fiber degradation (Khatab et al 2013). Rumen microbes convert protein and NPN into NH₃ which is utilized by the microbes for the synthesis of microbial cell protein (Salami et al 2021). Nitrogen supports the growth of fiber-digesting (cellulolytic) bacteria, enhancing fiber breakdown and improving rumen fermentation. Without adequate nitrogen, microbial activity drops, resulting in poor NDFD and lower production of volatile fatty acids (VFAs) like acetate and butyrate which are the primary energy source of ruminants, leading to poor animal performance (Rabee et al 2024).

Moreover, according to Hassanien et al (2025), the inclusion of mealworm frass at 3% on the diet of goats resulted in an increased digestibility coefficient for the DM and CP, increased VFA production, and ruminal ammonia concentration. In contrast, Astuti et al (2022) reported that the inclusion of cricket meals in the diet of goats showed no effect on the degradability of the animal. In addition, better degradability was observed in insect frass-based mineral blocks, this may also be because of the microbiological properties (bacteria, actinomycetes, fungi, and yeast) of frass that could help improve the degradation of fibrous forage material (Ainta et al 2023).

Table 5. In vitro degradability of napier grass

Component (%)	Treatment				SEM	p-value
	A (Control)	B (UMMB)	C (SWFMB)	D (BSFMB)		
Feed	87.4	84.8	88.4	97.7	3.46	0.1199
IVDMD	78.2	77.9	78.3	77.8	0.45	0.8229
IVCPD	69.7	78.1	79.9	68.7	6.38	0.8664
IVNDFD	66.6	60.9	68.1	68.3	2.31	0.1172
IVADFD	64.5	65.3	66.1	69.6	2.61	0.6804
IVCAD	15.5	19.9	16.1	17.1	1.59	0.2662
IVOMD	84.5	80.0	83.9	82.9	1.59	0.2662

* - significant at the 0.05 level, UMMB - urea molasses mineral block, SWLFMB - superworm larvae frass mineral block, BSFLFMB - black soldier fly larvae frass mineral block, IVDMD - in vitro dry matter digestibility, IVCPD - in vitro crude protein digestibility, IVNDFD - in vitro neutral detergent fiber digestibility, IVADFD - in vitro acid detergent fiber digestibility, IVCAD - in vitro crude ash digestibility, INOMD - in vitro organic matter digestibility

Conclusion

Insect frass-based mineral blocks, particularly those derived from SWL and BSFL present as a promising alternative to conventional supplements for goats. These mineral blocks offer valuable sources of protein, NPN, and minerals. Among the formulations, SWLFMB exhibited superior hardness and compactness, while UMMB demonstrated better solubility. Moreover, *in vitro* studies indicated enhanced feed degradability with insect frass supplementation. These findings highlighted the potential of insect frass as a functional and sustainable ingredient in ruminant nutrition.

References

Adewumi O. (2013). Physico-chemical properties and storability of urea molasses multi-nutrient feed block (UMMB) as dry season supplement for ruminants. *Journal of Applied Agricultural Research* 5(1):113-121

Ainta P, Attasopa K, Kaeomuangmoon T, Khongdee N, Khomampai J, & Chromkaew Y. (2023). Potential of insect frass as a bio-organic fertilizer from super worm (*Zophobas morio*) and mealworm (*Tenebrio molitor*). Chiang Mai University, Thailand

Aksoy M, Eljack R, Aksoy J, & Beck B. (2022). Frass from Black Soldier Fly Larvae, *Hermetia illucens*, as a Possible Functional Dietary Ingredient in Channel Catfish Feed. *Fishes*, 8(11):542.

Association of Official Analytical Collaboration. (2006). Official Methods of Analysis AOAC International 18th Ed. Gaithersburg, MD.

Asaolu V. (2012). Development of moringa multi-nutrient block as a dry season feed supplement for ruminants. *Livestock Research for Rural Development* 24(3) Accessed 11 September 2024 from <http://www.lrrd.org/lrrd24/3/asao24046.htm>.

Astuti D & Wiryawan K. (2022). Black soldier fly as feed ingredient for ruminants. *Animal Bioscience*, 35(2):356-363.

Dragojlovic D, Duragic O, Pezo L, Popovic L, Rakita S, Tomicic Z, & Spasevski N. (2022). Comparison of Nutritional Profiles of Super Worm (*Zophobas morio*) and Yellow Mealworm (*Tenebrio molitor*) as Alternative Feeds Used in Animal Husbandry: Is Super Worm Superior? *Animals* 12(10):1-16

Eisa M, Ragauskaitė D, Shi J, Shimizu S, Bucko T, Williams C, & Baltrusaitis J. (2023). Interactions of Urea Surfaces with Water as Relative Humidity Obtained from Dynamic Vapor Sorption Experiments, In Situ Single-Particle Raman Spectroscopy, and Ab Initio Calculation. *ACS Earth and Space Chemistry*, 7 (10) :2139-2153.

Garttling D, & Schulz H. (2021). Compilation of Black Soldier Fly Frass Analyses. *Journal of Soil Science and Plant Nutrition*. 22:937-943

- Gurung N. (2020). Nutritional Requirements of Different Classes of Meat Goats. *Professional Agricultural Workers Journal* 6(3):1-11
- Hassanien H, El-Fadel M, El-Badawy M, Phillip Y, Hussein A, Khayyal A, . . . Lackner A. (2025). Dietary inclusion of *Tenebrio molitor* L. frass affects nutrient digestibility, ruminal fermentation activities, blood metabolites, and milk performance in goats. *Journal of Agriculture and Food Research*, 19 : 101727.
- Kara K. (2019). The in vitro digestion of neutral detergent fibre and other ruminal fermentation parameters of some fibrous feedstuffs in Damascus goat (*Capra aegagrus hircus*). *Kara K. The in vitro digestion of neutral detergent fibre and other ruminal fermentation parameters of some fibrous feedstuffs in Damascus goat (Capra aegagrus hircus)*. *Journal of Animal and Feed Sciences*, 28(2):159-168.
- Kasprzak D & Galiński M. (2023). Chitin as a universal and sustainable electrode binder for electrochemical capacitors. *Journal of Power Sources*, 553 (1) :232300.
- Khattab I, Salem A, Abdel-Wahed A, & Kewan K. (2013). Effects of urea supplementation on nutrient digestibility, nitrogen utilisation and rumen fermentation in sheep fed diets containing dates. *Livestock Science* 155(2): 223-229.
- Liang J, & Paengkoum P. (2019). Current status, challenges and the way forward for dairy goat production in Asia – conference summary of dairy goats in Asia. *Asian-Australas J Anim Sci.*, 32(8): 1233–1243
- Lopes I, Yong J, & Lalander C. (2022). Frass derived from black soldier fly larvae treatment of biodegradable wastes. A critical review and future perspectives. *Waste Management*.
- Loresco M, Banayo J, Roxas J, Saballo K, Yambao R, Centeno J, & Angeles A. (2020). Philippine Local Forages as Sustainable Feed Alternative for Dairy Cattle. *Dairy Training and Research Institute*. Accessed 5 August 2024 from <https://dtri.cafs.uplb.edu.ph/completed/philippine-local-forages-as-sustainable-feed-alternative-for-dairy-cattle/>
- Mattioli S, Fratini F, Cachiarelli C, Martines V, Tuccinardi T, Paci G., . . . Mancini S. (2023). Chemical composition, fatty acid profile, antioxidant content, and microbiological loads of lesser mealworm, mealworm, and superworm larvae. *Italian Journal of Animal Science*, 23(1):125-137
- Omoniyi L, Isah O, Adewumi O, Arigbede O, & Onwuka C. (2013). Physico-chemical properties and storability of urea molasses multi-nutrient feed block (UMMB) as dry season supplement for ruminants. *Journal of Applied Agricultural Research*, 5(1): 113-121. Accessed 5 August 2024 from https://www.researchgate.net/publication/256125361_Physico-chemical_properties_and_storability_of_urea_molasses_multi-nutrient_feed_block_UMMB_as_dry_season_supplement_for_ruminants
- Orden E, Del Rosario N, Veluz E, Orden M, Crisostomo C, Dela Cruz J, & Del Rosario L. (2023). Characterizing smallhold goat production system: Assessment of goat farmers management and production practices towards goat dairying in Central Luzon, Philippines. *International Journal of Agricultural Technology Vol. 19(4):1733-1752*.
- Rabee A, Ghandour M, Sallam A, Elwakeel E, Mohammed R, Sabra E, . . . Hafez O. (2024). Rumen fermentation and microbiota in Shami goats fed on condensed tannins or herbal mixture. *BMC Veterinary Research volume 20 (35)*.
- Roffeis M, Wakefeild M, Almieda J, Valada T, Devic E, Kone N, . . . Muys B. (2018). Life cycle cost assessment of insect based feed production in West Africa. *Journal of Cleaner Production*, 199:792-806.

- Salami S, Moran C, Warren H, & Pickard J. (2021). Meta-analysis and sustainability of feeding slow-release urea in dairy production. *PLoS ONE* 16(2).
- Triunfo M, Tafi E, Guarnieri A, Scieuzo C, Hahn T, Zibek S, . . . Falabella P. (2021). Insect Chitin-Based Nanomaterials for Innovative Cosmetics and Cosmeceuticals. *Cosmetics*, 8 (2) : 40.
- Upadhyay N, Tiwari M, Pandey L, Karki T, Acharya R, Gairhe S, & Acharya Y. (2020). Economic analysis of the urea molasses mineral block (UMMB) feeding to lactating cattle in Nepal. *Nepalese Journal of Agricultural Sciences*, 19:2091- 0428.
- Yami A. (2007). Feeding management of Sheep and Goats. Technical Bulletin No.1. Ethiopia Sheep and Goat productivity Improvement Program. USAID. Accessed 5 August 2024 from <http://40.65.112.141/AIGR/tb/TB%201%20Urea%20Molasses%20Block.pdf>
- Van Soest P & Robertson J. (1991). Systems of Analysis for evaluating fibrous feeds. In W. Eds Pidgen, C. Balch, & M. Graham, *In standardization of analytical methodology for feeds* (pp. 49-60). International Development and Research Center, Ottawa, Canada