P-ISSN: 2618-0723
E-ISSN: 2618-0731

Extension Journal

NAAS Rating: 5.04
www.extensionjournal.com

International Journal of Agriculture Extension and Social Development

Volume 7; Issue 1; Jan 2024; Page No. 318-323

Received: 26-10-2023
Accepted: 01-12-2023

Indexed Journal
Peer Reviewed Journal

Utilization of ruminal content from slaughtered animals: A review

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DOI: https://doi.org/10.33545/26180723.2024.v7.i1e.225

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Abstract

Rumen content is abundantly available at slaughterhouses. It is seen as a slaughter waste creating environmental pollution. Animal feed accounts for up to 70% of the overall cost of production. So feeding is typically the main factor restricting the production of cattle in underdeveloped nations. In recent years, there has been a significant surge in the utilization of ruminal content for creating various formulations and presentations in animal feed production. This includes both direct incorporation of ruminal content and its processing to generate commercial products. The rumen content is one of the uncommon components and is easily accessible at slaughterhouses. Furthermore, it is a good source of protein and energy (feed and microbial protein), vitamins and minerals, particularly vitamin B complex. The nutritional value of rumen contents differ mostly due to the radically varied compositions of rumen contents from various species of ruminants. There are numerous ways to increase the nutritional value of rumen content *viz,* incorporating blood meal, poultry manure, molasses, urea, enzymes, and fermented feeds like silage. The composition of rumen material may be based on the diet of animals. It is an affordable source of protein and energy while lowering feed costs and pollution. Some researchers have also concluded that animals' feed might include rumen contents without having a deleterious impact on diet that is acceptable and has no negative consequences on performance. The main object of this review article is to draw attention towards the nutritional value of ruminal content and its potential as an animal feed. Here in this review article, we have discussed about various methods for utilization of slaughter house origin ruminal content *viz,* ensiling of ruminal content, Ruminal content has found a diverse range of applications in various sectors. It is employed as a bio activator for fermenting goat manure to produce fertilizer. Additionally, spray-dried rumen fluid (SDR) serves as a valuable feed additive. Sun-dried bovine rumen content (SDRC) is utilized as an ingredient in rations for white leghorn layers. Furthermore, ruminal content contributes to biogas generation and bioenergy production. It also serves as a fertilizer for soybean and corn crops. In research settings, it can replace inoculum from cannulated cattle for feed evaluation. Moreover, ruminal content is employed as an organic fertilizer for pot cultivation of vegetables and serves as animal feed for various species including poultry, fish, rabbits, quail, swine, sheep, and ducks.

Keywords: Ruminal content, bio gas, fertilizer, animal feed

Introduction

It comprises partially digested feed components, accompanied by rumen microorganisms, as well as various bioactive compounds including enzymes, minerals, vitamins, and organic acids. The release of Rumen content (RC) into the environment can cause soil and groundwater contamination due to its high nitrogen and phosphorus content. The solid component of the ruminal content cannot be processed within the municipal sewage system, leading to a challenge in its disposal. Rumen content is a significant portion of the daily wastes produced at slaughterhouses [1, 2]. Nonetheless, there is a drive to enhance the value of ruminal content obtained from slaughterhouses in order to mitigate both the production expenses in the livestock industry and the environmental pollution resulting from it [3].

In contemporary times, ruminal content is frequently applied as fertilizer on agricultural fields. Since ruminal content is a suitable livestock feed, this practice can address waste disposal issues and simultaneously lower feed costs. Slaughtering of cattle for meat has increased, and with it, rumen contents have increased, which has led to pollution problems in urban areas. Each cattle slaughtered would produce about 24.5 kg of fresh rumen contents or 3.8 kg in dry matter, since they contain 15.5% dry matter [4]. In India, an annual slaughter rate of approximately 50 million sheep and 2 million cattle is observed. If adequately collected and processed, these animals' ruminal content has the potential to yield around 4000-5000 tons of crude protein [5].

The challenge of high costs and limited availability of traditional animal feed is a significant issue in the commercial livestock production sector of developing and underdeveloped countries. To address this challenge, there is a growing interest in utilizing unconventional feed sources, which are typically not suitable for human consumption but offer a cost-effective alternative. Among these alternatives, slaughterhouse waste, particularly rumen contents (RC), stands out as a valuable option [6]. Nonetheless, researchers have succeeded in raising awareness among farmers about the potential to transform livestock waste into valuable animal feed. This highlights the importance of recycling various waste materials into ingredients suitable for livestock feed, effectively mitigating the competition between humans and animals for food resources. The practice of feeding livestock with abattoir waste, such as rumen content, leads to cost savings in feed and ultimately contributes to more affordable animal production [7, 8].

Use of rumen content as a major / minor component in silage: Ensiling is widespread in the preservation of agricultural products and forage crops. It has also expanded to include the conservation of protein-rich materials like fish and other animal by-products that would otherwise go to waste [9, 10, 11]. Ensiling appears to be a practical method for preserving rumen contents (RC). In 1972, Chittenden [12] documented the effective ensilage of rumen contents (RC) and ground corn stover, which were subsequently utilized as cattle feed. Additionally, Anthony (1970) [13] illustrated the nutritional significance of using a mixture of fresh animal manure and ground grass hay in a 57:43 ratio as a feed for ruminant animals.

In India, a significant proportion, approximately 65-70%, of animal slaughtering occurs in rural areas. Ensiling, as a preservation technique, is well-suited for rural settings, particularly for the conservation of rumen contents (RC) and blood obtained from small-scale abattoirs where only a limited number of animals are slaughtered each day [5].

Following are the different ways for utilization of rumen content: The utilization of ruminal content spans various applications, serving as a bio-activator and a key component in activities such as the production of sun-dried bovine rumen content (SDRC), biogas generation, and bio-energy production. It also finds value as a fertilizer for soybean and corn crops, offers an alternative to inoculum from cannulated cattle in feed evaluation research, acts as an organic fertilizer for potted vegetable cultivation, and serves as a feed source for a range of animals including poultry, fish, rabbits, quails, swine, sheep, and ducks (as illustrated in Figure 1).

Ensilage is one of the ways to prevent spoilage, maintain nutritional value and to eliminate the typical odour of rumen contents. Ensilage is a preservation method performed by fermentation process where lactic acid act as a preservative. To increase the dry matter of rumen contents for ideal ensiling (35% DM), dried *Cassava pomace* has been added, while molasses was added to increase the water-soluble carbohydrate content [14].

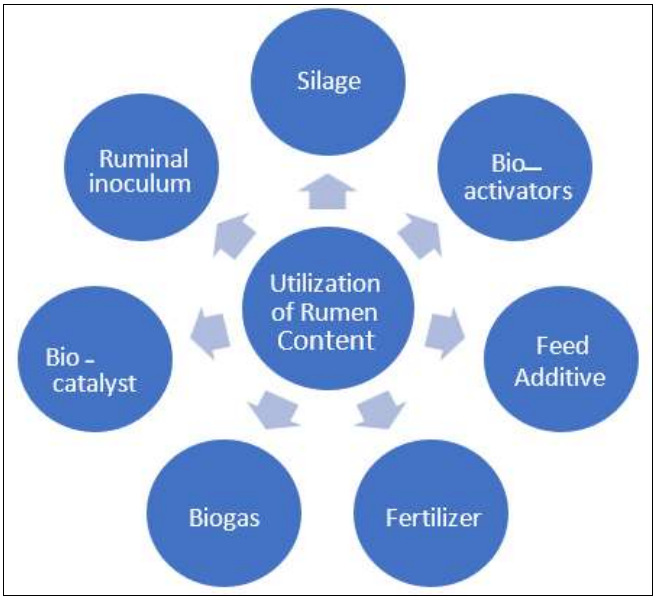

Fig 1: Utilization of Rumen Content

Ensiling by using dried *Cassava pomace*

In a study, silage was made from a mixture of rumen content and dried *Cassava pomace* (71.9:28.1) supplemented with molasses (4%) and *Lactobacillus plantarum* (0.01%). Fresh rumen content was collected from slaughterhouse, dried cassava pulp from cassava processing plant, molasses from sugar mill. Silage fed to cattle three weeks after completing the silage process.

Incorporating rumen content into silage as a substitute for forage, even up to 100%, led to a reduction in feed intake (FI), an increase in average daily gain (ADG), and improved feed conversion. However, when rumen contents silage was included up to 67%, it resulted in the highest carcass percentage. As a result, it was determined that the most effective utilization of rumen contents silage in the diet is up to 67% [14].

Ensiling using whole blood

Rumen contents and whole blood were combined in ratios of 2:1 and 1:1 by weight. These mixtures were then blended with ground wheat straw in different proportions: 70:30, 60:40, 50:50, and 40:60 by weight, both with and without the addition of dry molasses (5% by weight). These composite mixtures were subjected to ensilage for a duration of 6 weeks, contained within polyethylene bags. Various parameters, including weight, pH levels, dry matter content, lactic acid concentration, soluble carbohydrates, volatile fatty acids, and crude protein, were measured before and after the ensiling process. After the 6-week fermentation period, all of the silages exhibited desirable aromas, with pH values falling within the range of 4 to 5. Additionally, the levels of lactic acid and acetic acid were sufficient to ensure the preservation of most of the ensiled mixtures [5].

Utilized as bio-activators for fermentation in the production of goat manure fertilizer: Rumen contents are rich in potentially beneficial bacterial enzymes that serve as bio-activators during the production of goat manure fertilizer. A study conducted by Pancapalaga *et al*. (2021) [15] aimed to assess the quality of goat manure fertilizer by incorporating rumen content along with a 10% commercial starter solution and 5% molasses into buck manure. This mixture was allowed to undergo anaerobic composting for a period of 20 days, with regular checks on temperature and organoleptic quality performed every 3 days. The study results indicated that the most effective treatment involved the addition of 15% rumen content, which yielded the following composition: N 1.59%, P 0.15%, K 0.72%, organic C 30.60%, C/N ratio 19.24%, and moisture content 45.86%. Importantly, this composition adhered to the standards outlined in the Indonesian National Standard (SNI 19-7030-2004) for goat manure. In conclusion, the incorporation of rumen content into the mixture led to increased levels of N, P, K, organic C matter, and reduced the C/N ratio and moisture content, aligning it with the SNI 19-7030-2004 standards.

Utilizing Spray-Dried Rumen Fluid (SDR) as a Supplement in Animal Feed: This study was conducted to assess the potential of utilizing rumen fluid as a feed additive. Consequently, the impact of incorporating spray-dried rumen fluid (SDR) with 1% maltodextrin into the diets of pre-weaning dairy calves was investigated, focusing on performance, blood metabolites, and selected cytokines. The study involved forty male Holstein calves, aged 7 ± 1 days, with an average weight of 39.4 ± 3.7 kg. These calves were randomly distributed into four groups, each consisting of 10 calves, following a randomized design.
The experimental treatments included:
1. Control diet with no additive (CON)
2. Control diet with 0.5 g/day of SDR (SDR 0.5)
3. Control diet with 1 g/day of SDR (SDR 1)
4. Control diet with 1.5 g/day of SDR (SDR 1.5)

The study found that the daily feed intake and average daily gain of the calves were not influenced by the inclusion of SDR as a feed additive. Cholesterol levels were notably impacted on the 20th and 40th days of the experiment, exhibiting a linear decrease with increasing SDR intake. Furthermore, the levels of liver enzymes, specifically aspartate aminotransferase and alanine aminotransferase, in the blood decreased at day 40 with SDR supplementation. Serum interleukin-6 concentration at day 20 remained unaffected by dried rumen fluid feeding, but significant differences were observed among experimental treatments at day 40. On the other hand, serum interferon-γ concentration at day 20 was influenced by SDR supplementation, with the highest value recorded for SDR 1.5-fed calves. In conclusion, the incorporation of SDR with 1% maltodextrin in the diet of suckling dairy calves had positive effects on stimulating the calves' immune system [16].

As fertilizer in soybean and corn crops

The utilization of rumen contents (RC) as a fertilizer presents an environmentally friendly approach to managing this resource. A study (17) was conducted to assess the impact of an organic fertilizer derived from slaughterhouse waste on the fertility of both sandy and clayey soils, as well as its influence on soybean (*Glycine max* L.) and corn (*Zea mays* L.) crop yields.
The organic compost used in these experiments was a commercial product produced from various waste materials, with a notable emphasis on rumen content. It included tannery sludge, waxing and trimming waste, vegetable waste, coal boilers, sawdust, basalt powder, phosphorite, and talc. These materials were blended and mixed with an aqueous solution containing compost accelerator microorganisms, such as bacteria and fungi. The resulting product underwent a ten-day aeration process in conical cells before it was ready for use.
Field experiments were established, and various application rates of the organic fertilizer, ranging from 0 to 16 tons per hectare (293 kg/ha N, 334 kg/ha P, and 27 kg/ha K), were annually applied before spring/summer sowing. Additionally, mineral fertilization was provided at 300 kg/ha for soybean in the formulation 2-20-20 and 300 kg/ha for corn in the formulation 12-15-15.
The application of organic fertilizer significantly altered soil fertility in the field experiments, leading to increased levels of pH, Ca, Mg, K, P-Mehlich, and P-resin. These effects were more pronounced in sandy soils compared to clayey soils, with the uppermost soil layer experiencing the greatest impact. Notably, the study revealed a reduced requirement for organic fertilizer to achieve maximum crop yields, particularly for corn in both soil types and for soybean in sandy soil (see Table 1 for details).

Table 1: Doses of organic compost required to achieve maximum yield in trials with soybean and corn, harvested from 2009 to 2011.

	2009	2010	2011
	----------t of compost ha^{-1}----------		
Sandy soil			
Soyabean	27.9	17.9	14.5
Corn	17.0	13.8	11.4
Clayey soil			
Soyabean	20.8	14.0	13.2
Corn	14.8	12.5	10.2

(Nunes et al., 2015)

The reduction in the required application rate to attain peak yields, as well as to reach yields equivalent to those achieved with mineral fertilizers, aligns with the findings of Miller and Mackenzie (1978) [18]. In their research, they assessed various organic waste types and observed that sustained application resulted in higher yields compared to those achieved with mineral fertilization.

Incorporating Sun-Dried Bovine Rumen Content (SDRC) into White Leghorn Layer Diets

In a study by Gebrehawariat *et al*., (2016) [19], four distinct treatment diets were developed, denoted as T_1, T_2, T_3, and T_4, containing 0%, 5%, 10%, and 15% sun-dried rumen content (SDRC), respectively. This investigation concluded that incorporating up to 10% sun-dried rumen content into the diets of White Leghorn layers does not compromise their production performance or health status. The rumen content used in this study contains 11.18% crude protein and 1.22% ether extract.

Furthermore, the study found that as the level of rumen content increased, so did the daily dry matter (DM) intake. Birds fed a diet containing 10% SDRC exhibited a notably high DM intake. Additionally, there was a significant increase in the average egg weight with higher levels of rumen content in the diet.

These findings suggest that rumen content holds promise as a valuable feedstuff for layers, offering an economical and straightforward dietary option. Particularly during periods of feed scarcity and elevated conventional feed costs, SDRC emerges as a promising feed alternative.

Biogas generation using cattle rumen contents

Table 2: Average weekly production of biogas is:

Weeks	Biogas produced (cm^3)
1st week	40.25 cm^3
2nd week	178.5 cm^3
3rd week	386 cm^3
4th week	333.75 cm^3
5th week	219.75 cm^3
6th week	212.25 cm^3
7th week	198.75 cm^3
8th week	31.50 cm^3

Tambuwal *et al*., 2019 [24]

Biogas is a gas generated through the biological decomposition of organic matter in an environment devoid of oxygen. According to Singh (2012) [20], it is a clean biofuel produced by microorganisms during the anaerobic digestion of various organic materials, including cattle rumen content, cattle dung, poultry droppings, pig excreta, human excreta, and kitchen waste [21]. An effectively functioning biogas plant serves as a sustainable method for managing human-generated waste [22].

Biogas serves as an energy source generated through the cost-effective and efficient fermentation of organic materials like animal waste or agricultural by products. The significant advantage of biogas lies in its capacity to substitute other energy sources, such as charcoal, firewood, electricity, liquid petroleum gas, and oil. The fermentation process converts animal excrement into a high-quality substrate with reduced odor, making it superior to fresh manure for enhancing soil quality in agriculture. Furthermore, as an energy source, biogas helps combat deforestation and mitigates the negative environmental impacts associated with animal waste, including pollution, odors, flies, and water pollution in local communities [23].

In a study conducted by Tambuwal *et al*. (2019) [24], a biogas digester with a capacity of 500kg tins was designed and employed. The substrate used, primarily consisting of cattle rumen contents, was mixed in a 2:1 ratio with water. The digesters were agitated three times daily to prevent scum formation and facilitate the efficient release of produced gas. The retention time for this experiment was 56 days.

The highest gas production was observed on third week [Day 15-21(386 cm^3)], and then the production gradually reduces to 31.50 cm^3 on last week.

Utilization Rumen Fluid as a Biocatalyst for Bioenergy Production

This study investigates the application of rumen fluid as a biocatalyst in microbial fuel cells for the conversion of various market wastes into electricity. The process involves placing these waste materials into an anodic anaerobic chamber and then introducing rumen fluid obtained from a slaughterhouse. Notably, on the 19th day of the experiment, avocado fruit waste produced a voltage of approximately 0.584V, while the highest voltage recorded was 0.701V on the 20th day for tomato waste. In contrast, the mixture of watermelon and various fruits yielded the lowest voltage output. Among the waste materials tested, tomato waste exhibited the highest power generation. The power and current density ranged from 1.825 to 60.041 mW/m^2 and 6.762 to 99.174 mA/m^2, respectively, for tomato waste. Additionally, when 500ml of rumen fluid was used, the maximum voltage obtained from tomato waste was 0.584V, whereas avocado fruit waste generated 0.248V under the same conditions [25].

Substituting Slaughtered Cattle Ruminal Inoculum for Cannulated Cattle in Feed Evaluation Research

Slaughtered cattle's ruminal inoculum can effectively substitute inoculum collected from cannulated cattle in feed evaluation research involving *in vitro* gas production and digestibility assessments. To compare the two sources of inoculum, rumen fluid was collected from five adult Holstein × Zebu steers with ruminal cannulas. The study found no significant differences in *in vitro* dry matter digestibility (IVDMD), *in vitro* neutral detergent fiber digestibility (IVNDFD), and ammoniacal nitrogen concentrations between the two inoculum sources across various by-products and levels tested.

However, the total *in vitro* gas production in the ruminal inoculum from cannulated animals exceeded that of slaughtered cattle ($p < 0.001$), particularly when evaluating different levels of licuri cake. Conversely, the highest total concentrations of *in vitro* gases from slaughtered animals were observed when assessing various levels of crude glycerin ($p < 0.001$), with no significant differences noted for diets containing castor bean meal ($p > 0.05$). In conclusion, the ruminal inoculum obtained from slaughtered cattle is a viable alternative to using fistulated animals for digestibility analysis. This approach is ethically more humane as it eliminates the need for invasive procedures, thus reducing animal suffering [26].

Utilizing Rural Slaughterhouse Waste as Organic Fertilizer for Solanaceous Vegetable Pot Cultivation in India

Various parameters, including biochemical oxygen demand, chemical oxygen demand, total Kjeldahl nitrogen, oil and grease concentrations, total suspended solids, total solids, and total phosphorus, were monitored and analyzed over a five-day period. To create the 'bovine blood-rumen-digesta-mixture' (BBRDM), waste blood and rumen digesta were combined in ratios of 1:1, 2:1, and 3:1 and then dried. The efficacy of this organic fertilizer was compared to diammonium phosphate (DAP) in pot cultivation experiments involving tomatoes, chili peppers, and eggplants. Applying five grams of BBRDM (with an N/P/K ratio of 30.36:1:5.75) per kilogram of soil during the second and sixth weeks resulted in earlier fruiting by two weeks and significantly higher yields (total fruit weight) – 130% higher for tomatoes, 259% higher for chili peppers, and 273% higher for eggplants in BBRDM (3:1)-cultivated plants compared to those treated with DAP. Soils treated with BBRDM also exhibited higher concentrations of carbon, nitrogen, and phosphorus compared to DAP-treated soils. BBRDM with a high nitrogen content mineralized rapidly, making nitrogen and phosphorus available within six days of drying. While applying high nitrogen concentrations at planting could be toxic to young plants, BBRDM enhanced yield and productivity when applied to mature plants 15 days after planting. Furthermore, soils treated with BBRDM yielded higher populations of beneficial microorganisms such as Azotobacter, phosphate-solubilizing bacteria, and fungi, along with increased chlorophyll content. The carbohydrate, protein, and fat contents of the vegetables grown with BBRDM were comparable to those grown with DAP [27].

Utilizing Rumen Content as Animal Feed for Poultry, Swine, Sheep, and Ducks

In a laboratory-scale study conducted by Nova in 2000 [28], rumen content was fermented with Trichoderma harzianum. Feeding this fermented product to ducks resulted in significant weight gain, increased feed consumption, and improved feed conversion ratios.

Utilizing Rumen Content in Quail and Rabbit Feeding:

In the case of quails, Mishra *et al*. (2015) [29] reported that incorporating up to 30% dried blood rumen content in Japanese quail diets had no adverse effects on performance. In fact, feeding dried rumen contents led to a significant improvement in body weight, growth rate, and feed intake as the proportion of rumen contents in the diets increased [30].

For rabbits, when dried rumen contents replaced 25% of the hay in their diets, growth rates increased, as noted by AbdEl Rahman in 1989. However, it's important to mention that rumen contents do not ensile well, necessitating the addition of additional fermentable carbohydrates [31]. Ojebiyi and Saliu (2014) [32] documented that a mixture of rumen content and blood meal (50:50) can be included in the diets of growing rabbits, replacing 10% of groundnut cake and palm kernel cake without compromising growth performance. Moreover, including the blood-rumen content mixture up to a 40% level in the diets did not adversely affect performance, digestibility, blood parameters, or carcass measurements of growing rabbits [8].

Enhancing Nile Tilapia (*Oreochromis niloticus*) Fingerlings' Diets with Dried Rumen Digesta as a Soybean Replacement

Agbabiaka *et al*. (2011) [33] demonstrated that dried rumen content, when included at a 40% level, can effectively replace soybean in the diets of Nile Tilapia fingerlings (*Oreochromis niloticus*). This dietary substitution resulted in improved performance, increased body weight gain, and enhanced feed intake.

In an eight-week experiment, the nutritive potential of dried rumen digesta as a replacement for soybean meal in the Nile Tilapia diet was evaluated. One hundred and fifty Nile Tilapia fingerlings were divided into five groups, with Dried Rumen Digesta (DRD) replacing soybean meal at levels of 0%, 10%, 20%, 30%, and 40%, represented as T_1, T_2, T_3, T_4, and T_5, respectively, following a completely randomized design. The results indicated that all fish fed DRD-based diets outperformed those in the control group. This study revealed that including DRD at a 40% dietary level could effectively replace soybean in the diet of Nile Tilapia fingerlings without compromising their growth.

Conclusions

In conclusion, this review demonstrated that the rumen contents had a high nutritional value. Highly polluting abattoir wastes can be profitably used, reducing the negative environmental impact of their disposal and promoting a healthy environment around slaughterhouses. Rumen contents can be included in animal feeds because they are a cheap source of energy, protein, and other nutrients. Furthermore, it improves nutrient utilisation, lowers feed costs, and regulates waste disposal into the environment. As a result, the use of RC is recommended.

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