Utilization of Pineapple Waste as a Roughage Source Diets for Ruminant: A Review

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ABSTRACT
An important sector that can contribute sources of animal protein is ruminant livestock. Growth performance and meat quality were reported to be improved with high-fiber feeds. Pineapple waste as a feed ingredient has the potential to reduce dependence on grains and fodder crops during the dry season. The most widely grown plant in tropical countries is pineapple (*Ananas comosus* L.). Pineapple has been processed in fresh form such as: sliced, mashed, jam, chips, candy, dodol, and juice. The food industry processing of pineapple produces a large amount of waste, such as skin, crown tip, shoot tip, and core (50 -70%). The availability of pineapple in Indonesia is also high, around 2.4 million tons per year. If the waste is not handled, it will be difficult to dispose of and cause environmental problems. For this reason, the use of pineapple waste is reported to be used as a substitute for grass. The high content of crude fiber (39.75% on average) and carbohydrates (41.92%), as well as crude protein (6-8%), which is similar to Napier grass indicates that pineapple waste is a source of fiber for ruminants. This article aims to review the potential of pineapple waste as a roughage source of diets for a ruminant. This writing method used in this article is a literature study. Pineapple waste in ruminants is indicating to be suitable for use as a fiber source; this is evidenced by several research results carried out. In the form of fresh, dried, and fermented, Pineapple waste is reported to be used as additional feed and can replace 50% of ruminant forage in the total mixed ration. The use of pineapple stem processed into pulp is used as a fiber source with a balanced concentration level of 4 to 6 kg/head/day linearly increasing the intake of dry matter, protein, neutral fiber, and energy for the Holstein steer feedlot, and may also be beneficial for other ruminants. The price of feed is expected to be more efficient, cheaper and the sustainability of the livestock industry is maintained by utilizing pineapple waste as a source of fiber for ruminants.

Keywords: *diets, pineapple, waste, roughage, source, ruminants*

1. INTRODUCTION

Grazing conditions in grazing fields will be challenged by the increasing demand for land, air, and other sectors for human resources [1]. The sustainable livestock industry in feeding must be emphasized in increasing productivity by using existing resources. Many countries in the world feed livestock from agricultural and industrial by-products. This by-product has the potential to replace conventional ingredients in feed production [2]. These by-products or by-products are mainly disposed of improperly, causing adverse environmental which impacts on the environment [2]. Formation of carcass through consumption of feed by livestock will cause production costs to be high (60-80%) if it is still using conventional materials [3]. A solid and sustainable livestock industry needs quality and cost-efficiency feed rations. The Republic of Korea obtained analytical data showing the possibility of a 30% reduction in the cost of feed produced with alternative ingredients [4].

Alternative materials are obtained chiefly from agricultural and industrial by-products with well digestible cell walls and small indigestible residues. This indicates that the by-product can be used as animal

feed. Pineapple is mainly harvested in tropical countries in Southeast Asia, such as Thailand, the Philippines, Indonesia, and Malaysia, the largest pineapple-producing countries. In Africa, Kenya is also a critical pineapple producer. (*Ananas comosus* L. Merril) is massively produced globally. Pineapple has a delicious taste and is valuable and widely consumed by humans worldwide [5]. Pineapple is consumed fresh like a slice, chunks, crush, jam, chips, candies, *dodol*, and juice. Many vitamins and minerals are contained in pineapples [6]. During the processing of pineapple, residual is generated appreciable proportion of waste, such as peel, crown ends, bud ends, and cores (50-70%). Therefore, pineapple waste that can pollute the environment can be converted into helpful feed products. This can encourage sustainable livestock development as well as increase economic value and lower feed prices.

Indonesia produced a total of 2.4 million tonnes of pineapple in 2020. The harvested area was around 27,750 hectares. Residues from the pineapple processing industry that do not receive attention will be difficult to dispose of and cause environmental problems [7]. Of these, pineapple waste after vegetative shoots is removed. The content of fiber, starch, and bioactive compounds in pineapple waste is relatively high, but the protein content is low [8]. The crude fiber content of pineapple waste (an average of 39.75%) and carbohydrates (average 41.92%), but crude protein only ranged (6-8%), which was similar to Napier grass. The content of this waste shows the potential of this waste as a source of fiber for ruminants.

The results of research from [9] stated that the by-product of pineapple waste contained much higher nitrogen-free extract (75.06%) compared to Napier grass (43.80%) and Calliandra (50.28%) so that the increase in substitution of these by-products could provide a considerable contribution to the nitrogen-free extract content of the treatment feed. [10] stated that the use of pineapple waste silage as a substitute for grass showed no difference in the performance of farms whether or not given pineapple waste. The use of fruit waste such as pineapple in substituting sorghum did not affect the digestibility of dry matter, organic matter, crude protein, and TDN. The use of fruit waste (pineapple) is a good option to substitute sorghum silage and possibly to reduce feed costs [11].

Pineapple by-products are low in protein and NDF content. This is evidenced in studies on cattle and other ruminants, that the digestibility coefficient is high for the nutrients contained in pineapple waste, pineapple waste if equipped with the correct feed ingredients, will be able to overcome the scarcity of forage significantly [8]. Pineapple and its stems are rich in the proteolytic enzyme Bromelain which is widely found in pineapple and its stems. Protease has high hydrolytic activity in feed ingredients such as fish meals and soybean meals. The bromelain enzyme contained in pineapple waste possibly can increase protein degradability in the digestive tract [42].

The use of pineapple waste as silage for dairy and cattle has shown that pineapple waste silage can replace 50% of fiber sources in feed without unwanted effects [12], according to [8] using pineapple waste in fresh form by 30 to 100% as a fiber source of beef cattle [8]. Corn straw silage can also be replaced by pineapple waste silage up to 60% without adverse effects on growth and carcass characteristics of livestock [13].

This article aims to review the potential of pineapple waste as a fibrous source of diets for ruminant livestock. The writing method used in this article is a literature study. Some studies have shown that the use of pineapple waste in ruminant livestock is suitable for use as a fibrous source.

2. PINEAPPLE WASTE

Pineapple waste from the pineapple processing industry is commonly found in Indonesia because pineapple is a tropical fruit that has high nutritional content, good taste, and is liked by consumers. The pineapple processing industry leaves waste in the form of pulp and skin. However, there are still many unused parts of the pineapple, such as leaves, stems, outer skin, and others. This waste can be used as a new product that has economic value. The use of pineapple waste has recently become widespread and has given many problems to the environment and energy. Efficient management of pineapple waste is highly recommended, and in a sustainable manner an effective strategy will be found in reducing the negative impact on the environment by reducing pineapple waste into more useful products. In this context, the use of pineapple waste as another source of production has been emphasized.

Pineapple waste is relatively low or poor in protein (4-8% DM) and high in crude fiber (16-25% DM) and NDF (60-72% DM). Pineapple waste contains a lot of soluble sugars (40-75% DM; about 70% sucrose, 20% glucose, and 10% fructose) and pectin [8]. Pineapple waste is a low nutrient feed [14]. Pineapple waste is reported to be comparable to cereal grains for livestock due to its high variability, for ruminants [8]. The high amount of fiber makes pineapple waste widely used for ruminant animal feed compared to pigs and poultry. The large size of pineapple waste can limit feed intake [15].

2.1. Leaf of Pineapple

Leaves are one of the unused pineapple waste. world awareness needed for commercial exploitation in order to increase profits for the industry. Pineapple leaves are a medium-quality source of fiber for ruminants. It is

possible to allow cows or other ruminants to graze with pineapple leaves, but the leaves tend to be thick and it is advisable to cut the leaves [11]. Pineapple leaves can be used fresh, dried, or pickled. Leaves must be cut before use. It is recommended to ferment pineapple leaves with molasses. Although pineapple waste feed is relatively low in protein and high in fiber, this feed can be given to ruminants 15-20 kg per day either fresh or fermented. plants when other feed is rare. The dried leaves can be beneficially pelleted [12]. Because pineapple leaves have a low and poorly digestible protein content, supplementation with protein sources is needed [13].

2.2. Skin or Peel

Pineapple is a fruit that is commonly found in the tropics and is consumed in Indonesia. Pineapple waste such as skin or crown is unused waste and can pollute the environment, pineapple skin has the potential to be utilized. This waste can be used as organic fertilizer with other materials. Many studies were initiated to turn pineapple waste into animal feed, and other products. Animal feed using pineapple waste in combination with other ingredients could increase productivity [14]. Production of animal feed concentrate using soursop (Graviola) and fermented pineapple peel was studied [15]. Various studies have shown that pineapple peel is a medium for fungal growth because there is a breakdown of high carbohydrate concentrations.

2.3. Crown

Pineapple waste in the form of crowns is a source of essential cellulose which will still be wasted due to lack of knowledge in processing, using, and about its economic uses. The high fiber contained in pineapple crown, therefore, serves as an energy source in animal feed [16]. High water content in pineapple waste can reduce the quality of animal feed produced if it is not appropriately handled.

2.4. Core

The core of the pineapple may appear firm, less juicy and less sweet than the fruit. Pineapple core is also a source of fiber and can support a potentially healthy digestive system [17]. Pineapple core flour contains 99.8% of the total fiber content [18]. Therefore, pineapple core is an excellent source of fiber to be used as a quality feed.

3. PROCESSES

3.1. Fresh

Fresh pineapple waste as a by-product of the pineapple canning industry contains a lot of water (about 80-90%). The content of dissolved carbohydrates in it, will cause rapid decay. Consuming pineapple waste as soon as possible will reduce waste and spoilage. Pineapple processing industries are often not located in livestock areas; this causes the transportation needed to transport pineapple waste products is quite expensive [19]. Because of the speed of decomposition of pineapple waste, processing by drying techniques either from direct solar radiation or using a dryer needs to be done. [20].

3.2. Drying

Fresh pineapple waste can be dried in the sun in 3 days or dried by means of a tool in one day [21]. Drying with solar radiation either partially or completely may be difficult to do in the rainy season [22].

In Brazil, a by-product of dried pineapple replaces 100% *Cynodon dactylon* straw in feed for female goats. this can improve nutrient digestibility and result in the expected increase in body weight [23]. Feed in the form of pellets can be formed from pineapple waste such as leaves (crowns) and stems by mashing and mixing with other feed ingredients according to livestock needs to be used as feed for birds and other pets such as ruminants. The high fiber content of pineapple leaf waste, when applied as dairy animal feed, would increase milk production [16]. Bulk density of 300.56-343.33 kg/m^3, true density of 1,474.33-1,513.67 kg/m^3, hardness and porosity of 1.05-3.9 kg/cm^2 and 76.71-80.14%.

The high antioxidants and phenolics contained in pineapple fruit products, these contents will be able to improve health [26]; feed from pineapple waste products given for 80 days to goats shows an increased growth rate [22]. Variables of weight gain, feed intake, and feed conversion in the function of increasing levels (33; 66 and 100%) of dehydrated pineapple by-products in the ratio showed no significant difference [22].

Feed block is a form of animal feed processing that can be used for ruminants. Block feed uses a mixture of forage, concentrates, and other additional nutrients in the proportions needed to meet the nutritional needs of livestock [27], [28]. Block feed containing pineapple waste (crown, skin, and pomace) with rice straw at a moisture content of 8.7% (wet basis) plus molasses as a binder could be prepared and used for ruminant feed [29]. The study also found that using pineapple waste into block feed is a good alternative because it is relatively more stable during storage than conventional feed ingredients for livestock.

3.3. Ensilage

The water content and high acidity in pineapple waste make the silage process with a bran mixture difficult. Mixing with straw, wilted grass or rice straw with pineapple waste can be done in the silage process [30], [31]. Starch sources can improve the fermentation

process, such as molasses, corn, or sweet potatoes [21]. In one experiment, fermented pineapple waste (with or without rice straw) had a dry matter content lower than the optimal range of good silage and yielded good silage. The high carbohydrate content of pineapple waste, especially fructose which is converted into lactic acid by lactic acid bacteria, makes this silage has a good range [32].

Scarcity of feed in the dry season for goats can be overcome by pineapple pulp silage which is a good source of feed for goats, and pineapple can make pineapple pulp silage by mixing copra in the ration (at 25% as dry matter (DM) feed level) [33]. Nigeria, which is a pineapple producing country, makes silage to overcome feed shortages in the dry season from a mixture of pineapple pulp, young lima beans (*Phaseolus lunatus*), and fresh Napier grass (*Pennisetum purpureum*), this pineapple waste silage can increase feed protein content, digestibility, absorption, and retention of nitrogen, as well as preventing weight loss in goats [34] reflected optimal growth rate and body weight gain were reflected in livestock fed silage made from lima beans, pineapple pulp, compared to silage made from lima beans, peanuts cajan (*Cajanus cajan*), or African sweet potato (*Sphenostylis stenocardia*) [34]. [35] reported that a bagasse-vinasse mixture (70:30) could be used with sweetcorn husks, cobs, and pineapple peels to produce silage, and could be used to replace conventional materials as a total feed mix for cattle fattening**.**

4. UTILIZATION

The potential use of pineapple waste for animal feed has been reported by many researchers. Pineapple waste or its by-products have long been used as feed for ruminants. Many studies support the use of pineapple waste for feed in beef cattle and dairy cattle [8]. The use of pineapple waste mostly or entirely in fiber-rich feed will produce quality meat [36].

Pineapple juice by-product (without crown) contains higher energy, and it can be used to replace some of the energy in ruminant feed concentrates compared to corn silage [37]. Pineapple waste contains low protein and minerals. Supplementation is necessary to prevent adverse effects on productivity and health [8]. Several studies (Table 1) have investigated the average supply of pineapple waste for ruminant feed.

4.1. Feed Intake

A high CP:ME ratio in pineapple waste silage did not affect daily DM intake [38]. ME Intake per kgDM, net energy for maintenance (NEM) per kgDM, and net energy for growth (NEG) per kgDM were not affected by feed containing pineapple waste. Intake of dry matter, fiber, and concentrate was also not affected by fiber source from pineapple waste as feed [39]. Substitution of elephant grass with pineapple silage in the ration did not affect dry matter consumption (expressed in kilograms per day, %BW), OM, TC, NFC, and TDN [40].

4.2. Digestibility

The use of pineapple waste as animal feed requires a fairly short adaptation time for consumption by livestock [8]. Fermented pineapple waste is preferred by livestock compared to fresh waste [32]. OM digestibility values were reported in the range of 73-75% in cattle, sheep, and goats, this indicates pineapple waste is easily digested by ruminants. the increase in digestibility in total carbohydrates indicates that it is feasible to replace elephant grass with pineapple silage [40].

4.3. Rumen fermentation

Fed with pineapple stem by-product were natural pH

Table 1. The average recommended pineapple waste supply for feed of ruminant livestock

Amount of Pineapple waste	Authors
20% pineapple stem silage on an as dry matter (DM) basis feeding level for Holstein steers	Hattakum *et al.* (2019)
10.6% pineapple silage on as fed basis can be used for feeding finishing Hanwoo steers	Choi *et al.* (2021)
758 g kg^{-1} for recovery in sheep	Alves *et al.* (2016)
25-100% pineapple by-product silage on an as dry matter (DM) basis feeding level for Santa Ines crossbred sheep	Cutrim *et al.* (2013)
30% dehydrated pineapple on an as fed basis feeding level for lambs	Almeida *et al.* (2018)
33%, 66%, 100% dehydrated pineapple on an as dry matter (DM) basis feeding level for growing goat	Costa *et al.* 2007

and NH_3-N concentration [41]. Cattle-fed pineapple silage had consistently higher total SCFA than those fed ground corn and ground cassava. However, the three starch sources showed that molar proportions of acetate, propionate, and butyrate are no different. Concentrations of NH_3−N and lactate were not different among treatments [39].

4.4. Growth performance

Silage feed containing Napier had a lower body weight (170,2 kg) compared to feed containing corn and pineapple silage with weight gains of 185.3 and 189.5 kg, respectively [41]. Bulls (Brahman × Thai) fed pineapple peel silage mixed with bagasse and vinasse showed the highest levels of ADG associated with NFE and gross energy of pineapple silage compared to sweet corn silage [35]. Body weight gain was found to be greater with feed containing a mixture of bagasse-vinasse including pineapple peel silage compared to the others.

Replacing elephant grass with pineapple by-product silage at an increasing proportion showed no significant difference for the variables of body weight (BB), final total weight gain (TWG), and daily average weight gain [40]. Replacement of elephant grass with pineapple waste silage does not affect livestock performance. Some adverse effects would arise with the use of pineapple waste canning products which were increased to 3.0% DM on growth performance [42]. Cows fed pineapple waste silage showed higher body weight gain and ADG than those fed corn [39]. As a by-product of the tropical fruit processing industry, pineapple stem starch can be applied as a feed ingredient for fattening cattle.

4.5. Carcass

The carcass characteristics of the rib eye area were much greater with the use of silage feed from pineapple stem by-products [41]. Growth and carcass appearance did not adversely affect the level of pineapple canning by-product 1.5% DM in the diet, therefore it could be used for finishing bulls [42]. Administration of bagasse-vinasse mixture with pineapple peel silage showed the highest average daily gain compared to other treatments [35].

4.6. Meat Quality

Carcass characteristics for pineapple stem by-product silage and corn silage diets included significantly larger rib eye areas [41]. Holstein crossbred steers fed pineapple stem by-product and corn silage had a rib eye area of 87.91 and 89.15 c4.1. Feed Intake.

A high CP:ME ratio in pineapple waste silage did not affect daily DM intake [38]. ME Intake per kgDM, net energy for maintenance (NEM) per kgDM, and net energy for growth (NEG) per kgDM were not affected by feed containing pineapple waste. Intake of dry matter, fiber, and concentrate was also not affected by fiber source from pineapple waste as feed [39]. Substitution of elephant grass with pineapple silage in the ration did not affect dry matter consumption (expressed in kilograms per day, %BW), OM, TC, NFC, and TDN [40].

4.7. Blood parameters

Increasing the by-product of pineapple canning in the feed would decrease serum albumin concentrations [42]. Increased by-products of pineapple canning in feed will cause the serum concentration of glutamic-oxaloacetic transaminase to increase. The concentrations of cholesterol, triglycerides, and protein density were very low [39]. LDL levels in pineapple silage diet decreased relatively.in a feeding duration.

4.8. Performance of dairy cattle

Feeding a diet containing pineapple waste during the 90 days of the experiment resulted in an increase in cow's milk production by an average of 3.0 l per cow per day or a milk fat content of 0.6 U in cows [7]. Milk production showed no decrease. with a silage-based total mixed feed ratio compared to cattle-fed Napier feed. Waste products from the pineapple canning industry in China were used as animal feed [43].

4.9. Cost efficiency

The total cost of feed in the livestock industry is between 60 and 70% of the total production costs incurred in medium and large scale [44]. The energy source in the total mix ratio for fattening cattle could utilize pineapple peel silage and cassava chips due to its affordable price [35], [45]. The FCR was lower in pineapple silage fed by cattle than in corn-fed [39]. Benefits were obtained with feed using pineapple stem silage [41]. Prices issued are lower than others. Feed costs can also be reduced by replacing elephant grass with pineapple by-product silage [40].

5. ENVIRONMENTAL IMPACT

Improper and safe disposal of solid waste from the pineapple processing industry will have a serious impact on the surrounding environment [9]. The negative impact on the environment can be reduced by using pineapple industrial processing waste as animal feed. Recycling that can be applied is to use pineapple waste as animal feed, whereas manure is used as organic fertilizer for crop production, this is an example of an integrated system between crops and livestock that can increase economic value without harming the environment [46]. The development of food, medicine, and energy industries can be done from pineapple waste processing [47]. The sustainable use of pineapple waste

will increase the economic value for farmers and industry, and of course will reduce the level of pollution to the surrounding environment.

To encourage the development of the conversion of pineapple waste into other valuable products such as animal feed, pulp and paper, and other products, the management of the use of pineapple waste has been extensively researched. Pulp and paper can be produced using pineapple waste (skin) [49]. The development of animal feed with a combination of pineapple waste can be applied [14]. The production of mixed feed concentrates for livestock can use soursop (Graviola) and fermented pineapple peel [15]. Pineapple waste is a promising alternative feed for ruminant feed that can replace conventional feed [50]. In addition, the reduction of negative environmental impacts can be reduced by the use or utilization of pineapple waste.

6. CONCLUSIONS

This study provides information and describes the use of waste as a source of ruminant feed which is expected to encourage the development of the livestock industry that implements price efficiency, innovation, sustainability. The application of innovation processes and technology to pineapple waste as feed allows obtaining products that have added value, economic value and environmental degradation. Waste treatment is expected to be one of the factors that can solve environmental problems and create opportunities to build profitable industries. A piece of information to inspire further research ideas that are still less explored and certainly can be applied to the livestock industry.

AUTHORS' CONTRIBUTIONS

All authors contributed equally. RWI designed the review, while AP, MA, and EP participated in interpretation. RWI wrote and revised the manuscript, while AP, MA and EP suggested the revision.

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