

Evaluation of Agro-Industrial By Products as Potential Local Feed for Ruminant Animals: Chemical Composition, Fiber Fractions and *In Vitro* Rumen Fermentation

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Abstract. Animals are considered as source of protein should be improved their productivity with the minimum cost production. Agro-industrial by products have been used as animal feed to reduce feed cost. The purpose of this study is to evaluate agro-industrial by product in Aceh as potential local feed for ruminant animals based on chemical composition, fiber fraction and *in vitro* rumen fermentation. There were eight sources of agro-industrial by products (sago residues, coconut meal, soybean-ketchup by product, coffee pulp, cacao pod, sago tree, corncob, and rice brand) which were collected from 3 different locations in Aceh. All agro-industrial by product samples were dried at 60°C for 24 h and ground to pass a 1 mm sieve. Grounded samples were analyzed to determine chemical composition, fiber fractions and *in vitro* rumen fermentation. Incubation was conducted at temperature 39°C for 48 h in water bath with three replicates. Data for *in vitro* rumen fermentation were statically calculated by using SPSS differences between treatments were stated ($P \leq 0.05$) by using Duncan Multiple Range Test (DMRT). The results indicated that agro industrial by product from coconut meal, ketchup residues, coffee by product, cacao by product, and rice brand can be used as source of protein and industrial by product from sago by product, sago tree and corncob can be used as source of energy. *Neutral detergent insoluble CP* (NDICP) and *Acid detergent insoluble CP* (ADICP) were relatively high for sago by product, sago tree and rice brand but relatively low for cacao by product and corncob. The value of incubated pH for most feed samples was in the normal range. *In vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) were significantly difference ($P \leq 0.05$) each agro-industrial by products with the highest for sago and the lowest for coffee by product. In conclusion, agro-industrial by products had a potential feed for ruminant animals both as protein and energy sources. However, feed ingredients with high fiber content and low degradability, further treatments such as physical, chemical and biological treatments were required to improve the feed quality.

Keywords: Agro-industrial by products, ruminant, feed, and *in vitro*.

Abstrak. Ternak merupakan sumber protein hewani perlu ditingkatkan produksinya dengan biaya minimal dan memanfaatkan limbah industri pertanian sebagai sumber bahan pakan. Tujuan dari penelitian ini adalah mengevaluasi limbah industri pertanian sebagai sumber bahan pakan lokal ruminansia yang potensial di Aceh berdasarkan komposisi kimia, fraksi serat dan pencernaan *in vitro*. Delapan sumber bahan pakan yang berasal dari limbah industri pertanian (ampas sago, bungkil kelapa, ampas kecep, ampas kopi, kulit coklat, gerusan sago, tongkol jagung dan dedak) dari tiga lokasi berbeda di Aceh digunakan dalam penelitian ini. Sampel yang akan dianalisa (kandungan nutrisi, fraksi serat dan fermentasi rumen secara *in vitro*) terlebih dahulu dikeringkan selama 60°C selama 24 jam dan diigiling dengan ukuran 1 mm. Inkubasi dilakukan pada suhu 39°C selama 48 jam dalam *water bath* terdiri dari 3 ulangan. Data *in vitro* dianalisa secara statistik dengan menggunakan SPSS. Perbedaan antar perlakuan dinyatakan pada ($P \leq 0.05$) dilanjutkan dengan uji jarak berganda Duncan. Dari hasil analisa data didapatkan bahwa produksi limbah pertanian dari bungkil kelapa, limbah kecap, limbah kopi, limbah coklat dan dedak sebagai sumber protein, sementara limbah sago, gerusan sago dan tongkol jagung dapat digunakan sebagai sumber energi. Komposisi NDICP dan ADICP relatif tinggi pada limbah sago, gerusan sago dan dedak, namun relatif rendah pada limbah coklat dan tongkol jagung. Nilai pH pada semua bahan limbah pakan dari hasil fermentasi berada dalam kisaran normal. Kecernaan bahan kering dan dan pencernaan bahan organik setiap bahan pakan berbeda nyata ($P \leq 0.05$) pada setiap bahan pakan limbah industri pertanian yang tertinggi pada pada ampas sago dan yang terendah pada limbah kopi. Dari hasil penelitian dapat disimpulkan bahwa limbah industri pertanian lokal di Aceh dapat digunakan sebagai sumber bahan pakan ternak ruminansia baik sumber protein maupun sumber energi. Namun demikian, bahan pakan yang tinggi kadar serat dan rendah daya cerna perlu adanya perlakuan fisik, kimia dan biologi untuk meningkatkan kualitas bahan pakan dari limbah.

Kata kunci: Limbah industri pertanian, ruminansia, pakan dan *in vitro*

Introduction

Sustainability with the principle of zero waste production is very important in facing the growth of world population up to 9 billion in 2050. Animals are considered as source of protein should be improved their productivity with the minimum cost production. However, land cultivation for feed resource decreased due to land use for other purposes and feed production over the worldwide tended to reduce as result of climate change (Smith and Gregory, 2013). Therefore, efforts to find sources for alternative feedstuffs should be implemented as strategies to meet the need of feedstuffs in the future.

Agro-industrial by products as an alternative feedstuff have been used as animal feed to reduce feed cost (Mirzaei-Aghsaghali and Maheri-Sis, 2008; Samadi *et al.*, 2015a; Samadi *et al.*, 2015b). Agro-industrial by products is also a potential solution to provide protein and calories for animal production in worldwide. Utilization of agro-industrial by products supported political and social pressure to reduce pollution. Besides that, agro-industrial by products considered as residues can be utilized for other useful products like feedstuffs, fuel or fertilizer. Amongst them, feedstuffs had more economical values due to high cost of conventional feedstuffs. Even though, residue from agro-industries contain low nitrogen and high fiber contents (Aregheore, 2000), ruminants have ability to utilize fibers for their maintenance, growth, production and reproduction because of their rumen microbes.

Aceh Province has a number of agro-industries producing potential agro-industrial residues as alternative promising local ruminant feedstuffs. Several agro-industrial by product such as sago residues, coconut meal, ketchup residues, coffee pulp, cacao pod, sago tree, corncob, and rice bran have been identified in Aceh Province. Information relating to some potency of local feed as animal feedstuffs has

been published (Wahyono and Hardiyanto, 2008; Samadi *et al.*, 2010) with limited data for diet formulation. As a result, feed composition from National Research Council (NRC) is still used as reference for feed formulation in Indonesia. However, nutritional contents of feedstuffs highly varied depending on soil condition, climate and other environmental factors (Assefa and Ledin, 2001) and are not suitable to be used in animal feed formulation due to different nutritive values. Therefore, determination of nutritive values for local feedstuffs is required to support database for nutritionists in formulating feed by using local feedstuffs.

The feed quality was not determined not only by chemical composition but by other parameters as well such as fiber fraction and digestibility. Samadi and Yu (2011) and Samadi *et al.* (2013) determined energy and protein requirement for ruminant based on Cornell Net Carbohydrate Protein System (CNCPS) in which feed was divided in several carbohydrate and protein fractions. The purpose of this study is to evaluate agro-industrial by products as potential local feed for ruminant animals based on chemical composition, fiber fractions and *in vitro* rumen fermentation.

Materials and Method

Sample Collection and Preparation

Eight sources of agro-industrial by products (sago residues, coconut meal, soybean-ketchup by product, coffee pulp, cacao pod, sago tree, corncob, and rice bran) in this study were collected from 3 different locations in Aceh (Great Aceh, Bireun and North Aceh). Shortly after collection, all samples were kept in freezer (-20°C) for further analysis. Then, all agro-industrial by product samples were dried at 60°C for 24 h and ground to pass a 1 mm sieve by using hammer mill. All ground samples were then used for further chemical analysis to

determine chemical composition, fiber fraction and in vitro rumen fermentation.

Chemical composition determination

Chemical composition of samples were determined by proximate analysis consisting of determination of dry matter (DM), ash, organic matter (OM), crude protein (CP), ether extract (EE), and crude fiber (CF) based on AOAC procedures (AOAC, 2005). For a short information, DM content was determined by drying samples in an oven set at 105°C for 24 h. The content of ash was determined by burning samples in a furnace at 500°C for 3 h. OM was determined by calculating the difference between DM and ash. CP was determined based on Kjeldahl method with the following consecutive procedures; destruction, distillation and titration. Determination of CF was conducted by sequential boiling of samples in acid and alkali solutions each for 30 min. EE was determined by applying soxhlet extractor and petroleum ether to extract the fat content of samples.

Fiber Fraction determination

The method of Van Soes *et al.* (1991) were applied to determine the content of neutral detergent fiber (NDF) and acid detergent fiber (ADF). Sample were boiled in neutral detergent and acid detergent solutions for 1 h in sequential. Analysis of NDF was determined without α -amylase and sodium sulfite, and the value was expressed exclusive of residual ash. Determination of neutral detergent insoluble CP (NDICP) and acid detergent insoluble CP (ADICP) contents was by sing using method as described by Licitra *et al.* (1996). Samples to determine NDICP and ADICP were obtained from residual NDF and ADF analysis. All chemical composition and fiber fraction determination were performed in duplicate.

In vitro Rumen Fermentation

In vitro rumen fermentation was performed at the Laboratory of Nutrition and Dairy

Science, Nutrition and Feed Technology Department, IPB Bogor. The procedure of Theodorou *et al.* (1994) method were applied to determine IVDMD and IVOMD. Briefly, rumen fluid was collected in the morning before feeding through a rumen fistulated cow. Rumen fluid was filtered with four layers of gauze before using. A 125 ml serum bottle was prepared to fill in 0.75 sample and add 75 ml buffered rumen fluid with the ratio of rumen fluid : buffer (1.4 v/v). Incubation was taken place in a water bath with the temperature of 39°C for 48 h. After 48 h incubation. Supernatant obtained was analyzed to determine pH by using a pH meter. Residue was further incubated with 75 ml pepsin-HCl 0.2 N solution for another 48 h (Tilley and Terry, 1963). IVDMD and IVOMD were determined by subtracting residues of DM and OM from initial prior to fermentation, respectively. The in vitro incubation was conducted in three runs and two serum bottles represented for each run. In this experimental, different in vitro runs was considered as block (replicates).

Data analysis

All data were analyzed by using analysis of variance with the following statistical model:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$$

Where; Y_{ij} is the observed value, μ is the overall mean, α_i is the treatment effect, β_j is the block. differences between treatments were stated ($P < 0.05$) by using Duncan Multiple Range Test (DMRT). The statistical analysis was performed by using SPSS software version 9.1.

Results and Discussion

Chemical Composition

Chemical composition of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffee pulp, cacao pod, sago tree, corncob, and rice bran) as potential local feed for ruminant animals in Aceh Province is

presented in the Table 1. Dry matter content of agro-industrial from this study was from 82.45% to 91.68% with the highest organic content (88.20%) in corncob and the lowest organic content (51.70%) in ketchup residues. The highest content of ash in this study due to salty ketchup process. The ash content of corncob in this study was also higher compared to NRC (2000) and Yulistiani *et al.* (2012) with the ash content of 1,8% and 1,2% respectively. The highest protein content of agro industrial product in this study was 16.53% in coconut meal. It was lower compared to data published by NRC (2000) and Agustono *et al.* (2017). In this study, sago residues had the lowest protein content (1.10%) due to sago as source of carbohydrate. Kleden and Mariana (2018) stated that agro-industrial by product contained high in crude fiber and low in protein. Cacao pod had the highest of crude fiber content (29.6%). The results was different from Nuraini and Mahata (2009). Assefa and Ledin (2001) stated that nutritional contents of feedstuffs highly different depending on soil condition, climate and other environmental factors and to formulate feedstuffs as animal feed should be firstly analyzed. It should be also considered that some agro-industrial by product contained anti-nutritional factor as example of theoromin in cacao pod (Aregheore, 2000).

In our study, coconut meal contained the highest lipid (12.55%). Our lipid content result was similar reported by Agustono *et al.* (2017) with the lipid content of 12.55%. Coconut meal was the result of palm oil and usually still contained lipid in the residues. In our study, the lowest lipid content was in the sago residue with the amount of 0.24%. The highest content of nitrogen free extract (NFE) in our study was sago trees with the amount of 91.86. We used sago trees as part in our study since farmers in Aceh utilized this part of feedstuffs in their feed formulation. It could be source of information for the farmers. The lowest NFE was 34.56 in

the ketchup residues. NFE content in the feedstuff is highly dependent on the content of crude protein, ash, crude fiber and crude lipid.

Table 2 shows fiber fraction of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffee pulp, cacao pod, sago tree, corncob, and rice bran) as potential local feed for ruminant animals in Aceh Province. The results of the study indicated that cacao pod contained the highest level of NDF with 81.70% and coffee residues contained the lowest level of NDF with 38.58%. The NDF contain of cacao pod in our results was in accordance with the results from Laconi and Jayanegara (2015) with the amount of 80.70%. Compared with soybean as source of protein in animal feed, NDF content in agro-industrial by products was much higher (Samadi and Yu, 2011).

Ghodrat *et al.* (2017) stated that ADF in feedstuffs consisting of cellulose, lignin and heat-damaged protein in which protein was bound with lignin. NDF uses as fast method to measure fiber as substitution for crude fiber measurement. Among agro-industrial by products in our study, rice bran contained the highest of ADF content with the amount of 50.81% and sago had the lowest with the amount of 9.30%. ADF content of rice bran in our study was higher compared to Ghodrat *et al.* (2017) with the amount of 44.80%. Mirzaei-Aghsaghali (2008) presented some agro-industrial by products for ruminant animal including fiber fraction and conclude that agro-industrial by product had economical worthwhile due to high cost of conventional feed. ADF content containing agro-industrial by products higher compared with source of protein in feed such as soybean (Samadi and Yu, 2011).

Fiber reflected nutritional values of feedstuffs consisting of highly fermentable, less fermentable and purified fiber such as cell

Table 1. Nutritive values of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffee pulp, cacao pod, sago tree, corncob, and rice bran) as potential local feed for ruminant animals in Aceh Province

Agro-industrial by Products	DM (%)	OM (%)	Ash (%DM)	CP (%DM)	CL (%DM)	CF (%DM)	NFE (%BK)
Sago Residues	89.89	85.76	4.13	1.99	0.48	5.72	87.68
Coconut Meal	88.48	81.06	7.42	16.53	12.55	10.56	52.94
Ketchup Residues	82.45	51.7	30.75	15.42	10.79	8.48	34.56
Coffee Pulp	87.09	73.6	13.49	8.58	0.93	14.54	62.46
Cacao Pod	87.23	75.61	11.62	9.66	0.42	29.3	49
Sago Trees	89.6	85.83	3.77	1.1	0.24	3.03	91.86
Corncob	91.2	88.2	3	4.01	0.58	26.97	65.44
Rice bran	91.68	81.42	10.26	8.6	10.62	10.63	59.89

DM: Dry Matter, OM: Organic Matter, CP: Crude Protein, CL: Crude Lipid, CF: Crude Fiber and NFE: Nitrogen Free Extract

Fiber Fraction

Table 2. Fiber fraction of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffee pulp, cacao pod, sago tree, corncob, and rice bran) as potential local feed for ruminant animals in Aceh Province

Agro-industrial by Products	NDF (% DM)	ADF (% DM)	NDICP (% CP)	ADICP (% CP)
Sago residues	77.1	17.49	2.17	5.42
Coconut meal	27.99	15.4	1.54	1.53
Ketchup residues	58.43	31.79	1.71	0.91
Coffee pulp	38.58	21.04	1.37	1.14
Cacao pod	81.07	41.69	0.70	0.52
Sago trees	63.95	9.3	4.94	5.20
Corn cob	58.65	49.14	0.99	1.64
Rice bran	57.19	50.81	3.34	2.52

ADF, Acid detergent fiber; ADICP, Acid detergent insoluble crude protein; NDF, Neutral detergent fiber, NDICP, Neutral detergent insoluble crude protein.

wall. Protein binding to cell wall such as neutral detergent insoluble crude protein (NDICP) dan acid detergent insoluble crude protein (ADICP) was not available for animal as source of energy and protein. Samadi *et al.* (2013) stated that the content of NDICP and ADICP in the feedstuffs effected rumen degradation based on *in vitro* study. According to CNCPS system, characteristic of proteins in the feedstuffs was partitioned based on solubility and degradation in the rumen; rapidly degraded protein, slow degraded protein and not available protein. In our study, the content of NDICP and ADICP was mostly under 5%, except for several feedstuffs such as sago residues and sago tress containing ADICP of 5.42% and 5.20% respectively.

In vitro Rumen Fermentation

The value of pH, *in vitro* dry matter digestibility (IVDMD) and *in vitro* organic matter digestibility (IVOMD) agro-industrial by products (sago residues, coconut meal, ketchup residues, coffe pulp, cacao pod, sago tree, corncob and rice bran) as potential local feed for ruminant animals in Aceh Province after rumen fermentation are presented in

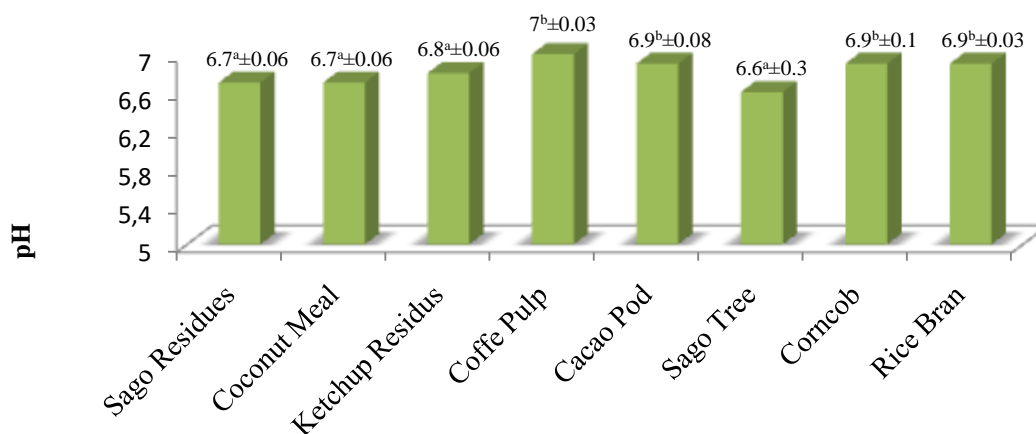
Figure 1, 2 and 3 respectively. Based on the statistical results, agro-industrial by products were significantly different ($P > 0.01$) amongst local feedstuffs for pH, IVDMD and IVOMD. The value of pH had an important role in degradability process of feedstuff in the rumen and supported the growth of rumen microbes. The highest of pH rumen agro-industrial by products in our study was 7.0 and the lowest was 6.6 for coffee residues and sago trees respectively. The value of pH was still in the optimal of microbe growth. According to Kopečný and Wallace (1982) proteolytic enzyme worked optimally in the range of pH 5.5-7.0. Study conducted by Cardozo *et al.* (2002) comparing to kind of feedstuffs high forage vs high concentrate with the pH from 4.9 to 7.0 concluded that degradation of protein was reduced along with decrease of pH value.

In addition, study conducted by Lana *et al.* (1998) also indicated that reduce of pH from 6.5 to 5.7 reduced the concentration of ammonia in the rumen, but this only for the cattle fed 100% forage. Wajizah *et al.*, (2015) reported that fermented oil palm fronds by *Aspergillus niger* with different soluble

carbohydrate had pH value with the range of 6.80-6.90. The research conducted by Devant *et al.* (2001) by using soybean meal and heat-processed soybean meal with the concentration of 60:40 (forage : concentrate) and beef cattle feed with the ratio of 10:90 (forage:concentrate) concluded that degradation of protein was lower in the beef cattle beef and pH was not only influencing reduction of protein degradation. In our study, lower pH in sago trees compared to others since not structural carbohydrates such as starch were quickly fermented to lactic acids and reduced the pH value.

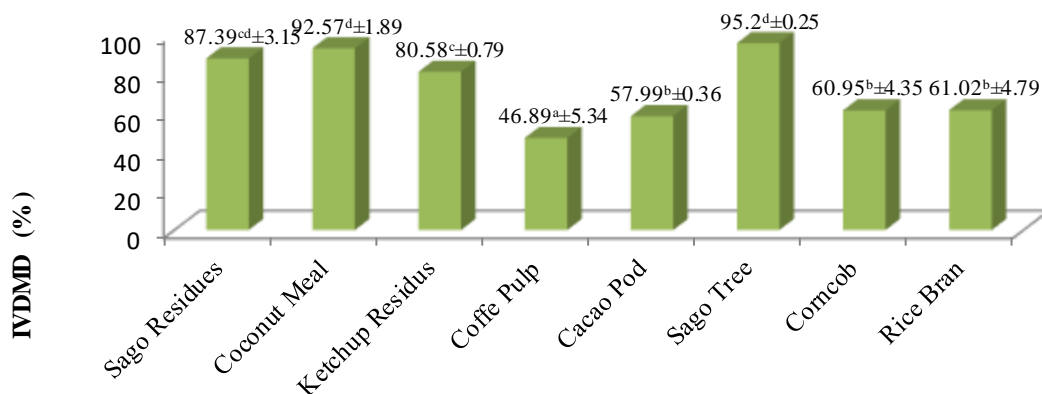
The percentage of IVDMD in our study was in the range of 46.89% - 92.20%. Coffee residues had the lowest of IVDMD (46.98%) due to high content of crude fiber in the coffee residues. Agro-industrial by products has been used to replace conventional feed

due to high cost of conventional feed. Study conducted by Seo *et al.* (2015) concluded that spent ground coffee can be used as alternatives to conventional feed by improving their nutrition composition and reduce cost. Fermentation of agro-industrial by product was able to improve production and bioactive content (Acevedo *et al.*, 2013), resulted in improving of feed digestibility. The value of IVOMD in our study was 42.27%-95.26%. The high content of IVOMD in some of ingredients in our study due to high starch content in sago trees. Formulation of cattle feed by using ground sago trees was intensively applied as one of the ingredients in ruminant feed formulation in Aceh. Fermentation of sago residues improved IVDMD and IVOMD to 19.34% to 22.19% due to feed fraction alteration after fermentation.



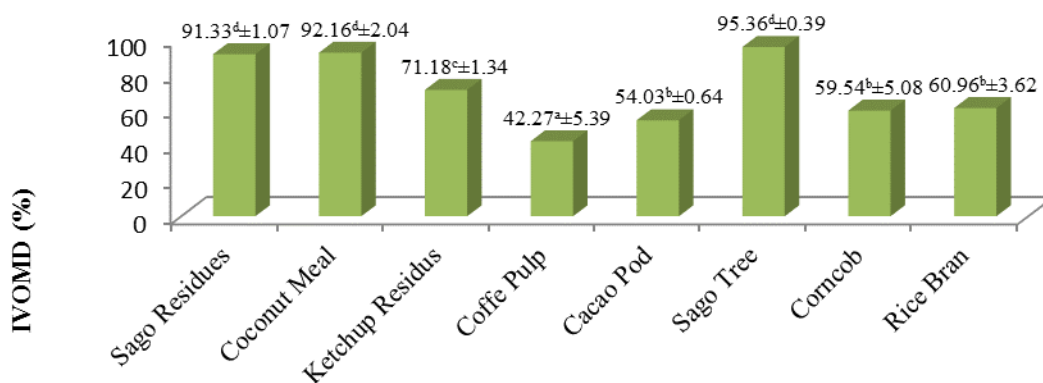
Agro-industrial By Products

Figure 1. pH values of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffe pulp, cacao pod, sago tree, corncob and rice bran) as potential local feed for ruminant animals in Aceh Province after rumen fermentation.



Agro-industrial By Products

Figure 2. IVDM of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffe pulp, cacao pod, sago tree, corncob and rice bran) as potential local feed for ruminant animals in Aceh Province after rumen fermentation.



Agro-industrials By Product

Figure 3. IVOMD of agro-industrial by products (sago residues, coconut meal, ketchup residues, coffe pulp, cacao pod, sago tree, corncob and rice bran) as potential local feed for ruminant animals in Aceh Province after rumen fermentation.

Conclusions

In conclusion, agro-industrial by products had a potential feed for ruminant animals both as protein and energy sources. However, feed ingredients with high fiber content and low degradability, further treatments such as physical, chemical and biological treatments were required to improve the feed quality.

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