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DEVELOPMENT OF PINEAPPLE WASTE PELLETS AND IN VITRO DIGESTIBILITY STUDY FOR HERBIVORE

MUHAMMAD FAKHRI BIN ZAINUDDIN

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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June 2015

Chairman : Rosnah binti Shamsudin, PhD
Faculty : Engineering

Pineapple agro-waste, the residue produced during harvesting or processing activities, is widely available around the world. After harvesting, most pineapple residue is disposed of and serves as fertiliser, or is burnt in an open field. However, these methods are not only ineffective, but also contribute to pollution. The objectives of this research is to provide value added products from pineapple biomass. Three different varieties of pineapple plant waste were chosen, namely Josapine, Moris and MD2. The physicochemical properties of these plants were determined by separating the leaves and stem from the plant. The analysis was done by using Thermogravimetric Analysis (TGA) and proximate analysis to determine the cell wall structure (hemicellulose, cellulose and lignin), and also the proximate content (moisture content, crude protein, crude fat, ash, crude fibre, carbohydrate). Proximate analysis showed that the nutrient content is available in the leaves and stems of the pineapple plant of the different varieties with almost similar values. Therefore, one of the possible ways to manage pineapple residues is by converting them into animal feed by a densification process. Densification of biomass feedstock, such as compaction and extrusion, can increase bulk density, improve storability, reduce transportation costs, and enable easier handling with proper storage equipment. The whole pineapple plant waste was converted to powder form, then extruded and also compacted by using an extruder and a compacter with five levels of moisture content (30 %, 35 %, 40 %, 45 % and 50 %). The findings of this study suggest that the moisture content from the extrusion process had no significant effect on the physical aspect of the pellet, except for the compaction process. An *in vitro* gas production was tested to the pellets to find the percentage of digestibility in rumen. This technique was continuously measured by incubating samples in buffered rumen obtained from a fistulated cow for 72 hours. Cumulative gas production, chemical composition (OMD, SCFA, NE_l, ME), rate of digestion of material and the pH of the rumen fluid were estimated. The chemical analysis and nutritional value of these pellets showed that they possess similar values with no significant difference ($p > 0.05$). However, pellets from the compaction process showed that they have a high digestibility rate with a significant effect ($p < 0.05$) compared to the pellets from the extrusion process. Thus, these pellets have the potential to become a good source of fibre for ruminants.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBUANGAN PELET DARI SISA BUANGAN POKOK NANAS DAN KAJIAN PENGHADAMAN *IN VITRO* UNTUK HERBIVOR

Oleh

MUHAMMAD FAKHRI BIN ZAINUDDIN

Jun 2015

Pengerusi : Rosnah binti Shamsudin, PhD
Fakulti : Kejuruteraan

Sisa agro dari pokok nanas adalah sisa yang terhasil selepas aktiviti penuaian dan pemprosesan, terdapat banyak di seluruh dunia.Selepas aktiviti penuaian, kebanyakan pokoknanas dibuang dan dijadikan baja, atau dibakar secara terbuka di lading. Walau bagaimanapun, kaedah ini bukan sahaja tidak berkesan, tetapi juga menyumbang kepada pencemaran udara.Objektif kajian ini adalah untuk menyediakan nilai tambahan produk daripada sisa buangan pokok nanas.Tiga jenis pokoknanas yang berbeza telah di pilih, iaitu Josapine, Moris dan MD2.Ciri-ciri kandungan fizikal-kimia telah ditentukan dengan mengasingkan daun dan batang daripada pokok nanas tersebut.Analisis telah dijalankan dengan menggunakan Analisis Thermogravimetrik (TGA) dan analisis proksimat untuk menentukan kandungan dinding sel (hemiselulosa, lignin dan selulosa); dan juga kandungan proksimat (kandungan lembapan, protin, lemak, abu, serat, karbohidrat).Analisis proksimat menunjukkan bahawa terdapat kandungan nutrien di dalam daun dan batang tumbuhan nanas yang pelbagai jenis dengan menunjukkannilai yang hampir sama. Oleh itu, salah satu cara yang mungkin untuk menguruskan sisa nanas di ladang adalah dengan menukarkan mereka ke dalam bentuk makanan haiwan melalui proses pemadatan. Pemadatan bahan biomas kepada pelet, contohnya seperti pemampatan dan penyemperitan boleh meningkatkan ketumpatan bahan, meningkatkan masa penyimpanan, mengurangkan kos pengangkutan, dan memudahkan pengendalian dengan peralatan penyimpanan yang baik. Keseluruhan sisa pokok nanas telah ditukarkan kepada bentuk serbuk, kemudian iatelah disemperit dan dipadatkan dengan menggunakan alat penyemperitan dan pemadatandengan 5 tahap kandungan lembapan (30%, 35%, 40%, 45% dan 50%). Hasil kajian ini mencadangkan bahawa kandungan lembapan daripada proses penyemperitan tidak mempunyai kesan yang besar ke atas aspek fizikal pelet, kecuali untuk proses pemadatan. Teknik pengeluaran gas *In vitro* telah digunakan terhadap pelet untuk mencari nilai peratus penghadaman pelet di dalam perut.Teknik initelah diukur secara berterusan dengan menginkubasi sampel dalam perut lembu berfistula selama 72 jam.Pengeluaran gas terkumpul, komposisi kimia (OMD, SCFA, NE_l, ME), kadarpenghadaman makanan dan pH cecair perut lembu telah dianggarkan. Analisis kimia dan nilai pemakanan pelet ini menunjukkan bahawa mereka mempunyai nilai yang sama dengan perbezaan yang tidak signifikan ($p > 0.05$). Walau bagaimanapun, pelet dari proses pemadatan menunjukkan bahawa mereka mempunyai kadar penghadaman yang tinggi dengan kesan yang signifikan ($p < 0.05$) berbanding dengan pelet dari proses penyemperitan. Oleh itu, pelet ini mempunyai potensi menjadi sumber serat baik untuk ruminant.

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I certify that a Thesis Examination Committee has met on 29th June 2015 to conduct the final examination of Muhammad Fakhri bin Zainuddin on his thesis entitled "Development of Pineapple Plant Waste Pellets and *In Vit*ro Digestibility Study for Herbivore" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the Thesis Examination Committee were as follows:

Siti Mazlina Mustapa Kamal, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Yus Aniza Yusof, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Dato' Abdul Wahab bin Mohammad, PhD
Professor Ir.
Universiti Kebangsaan Malaysia
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 2 November 2015

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Rosnah Shamsudin, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Noriznan Mokhtar, PhD
Senior Lecturer,Ing
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Dahlan Ismail, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

____

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature: ____________________
Name of Chairman of Supervisory Committee: Rosnah Shamsudin, PhD

Signature: ____________________
Name of Member of Supervisory Committee: Mohd Noriznan Mokhtar, PhD

Signature: ____________________
Name of Member of Supervisory Committee: Dahlan Ismail, PhD

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LIST OF ABBREVIATIONS

AOAC	Association of Analytical Chemists
ADF	Acid Detergent Fibre
ADL	Acid Detergent Lignin
NDF	Neutral Detergent Fibre
DM	Dry Matter
FAO	Food and Agricultural Organization
MARDI	Malaysian Agricultural Research Development Institute
MAEPS	Malaysian Agro Exposition Park Serdang
ME	Metabolisable Energy
NE_1	Net Energy of Lactation
OMD	Organic Matter Digestibility
SCFA	Short Chain Fatty Acid
TGA	Thermogravimetric Analysis
VFA	Volatile Fatty Acid

LIST OF NOMENCLATURES

ρb	bulk density
g	gram
kg	kilogram
%	percentage
h	hours
min	minutes
ml	milliliter
N	normality
%	percentage
MPa	Mega Pascal
rpm	rotations per minute
m	mass
v	volume
p	probability
°C	celcius
MJ	Megajoules
mmol	milimol

CHAPTER 1

INTRODUCTION

1.1 Research Background

Pineapple is the tropical fruit, largely produced after bananas, contributing to over 20 % of the world production of tropical fruits. Nearly 70 % of the pineapple is consumed as fresh fruit in the producing countries. Thailand, Philippines, Brazil and China are the main pineapple producers in the world supplying nearly 50 % of the total output. Other important producers include India, Nigeria, Kenya, Indonesia, México and Costa Rica and these countries provide most of the remaining fruit available (Medina and Garcia, 2005). Malaysia contributed over 0.7 % of the exported pineapple juice in the world, ranked 5th in Asia and 22nd in the world, with Asia remaining as a major supplier of pineapple juice (Parker, 2005). The pineapple (*Ananas comosus*) is the leading edible member of the family *Bromeliaceae*, and it is commercially produced as canned fruits and is consumed worldwide (Tran, 2006).

1.1.1 Economy

Malaysia was estimated to produce about 23 million tons of pineapple fruit, with an area under 995,888.39 ha of pineapple plantation in the year 2012 (FAO, 2014). The most commonly grown pineapple varieties in Malaysia are the Josapine, Moris, Sarawak, Gandol and N36. Most of these pineapples are grown on peat soil especially in the southern part of Peninsula Malaysia in the state of Johore (Rosnah Shamsudin et al. 2009). According to the Agrofood Statistics (2010), one hectare of pineapple field can produce about 17,400 fruits, which is approximately 25 metric tonnes of pineapple fruit. Agro-waste residue is taken from the processing of a particular crop or animal product usually by a farming-based industry. Materials in this category included brewer's wastes, maize milling by-products, oilseed cakes, bagasses and molasses. Crop residues include stubble, pulp, seed, lint, peel, shell, husk, leaves, stalk, stem, straw, etc. and also from palm oil, fruits (coco, mango, cashew, banana, pineapple), tea, olive, coffee, legumes (bean, tomato), jute, groundnut, cotton, cereals (barley, sorghum, maize, corn, wheat, rice) are considered agricultural wastes (Nigam et al. 2009). The increasing expansion of agro-industrial activities over the last few years has led to the accumulation of a large quantity of lignocellulosic residues all over the world. In 2010, the total estimated amount of pineapple leaves produced in Malaysia itself was around 28,469 metric tons (Wan Mohd and Zainuddin, 2013). It is very essential to convert this residue into value added products in order to give benefit both for the environment and economic viability.

1.1.2 Environment

The agro-waste residue is produced after harvesting the fruits and it has become an issue since the agro-waste residue cannot be disposed of properly without open-field burning. Carbon dioxide (CO_2) together with carbon monoxide (CO) and unburnt carbon(CH_4) are released together with nitrogen oxides (NOx) and a relatively smaller amount of sulphur dioxides (SO_2) during the process of open-field burning (Butchaiah et al. 2009).

Herbivorous animals in many tropical countries survive mainly on crop residue based diets. Based on a study by Kellems et al. (1970), ruminants in tropical areas, where pineapple are easily grown, can use the pineapple plant residue as a forage resource for animal-feed production. However, the crop residues are taking up a lot of space for its weight and also fibrous. Furthermore, when these materials are available in bulk, these feed resources are not well managed. The efficiency of utilisation of this high potential feed resource will be optimised if management in the crop residues are improve. For the commercial manufacture of pineapple plant waste-based feed for herbivores, processing technology is one of the options for effective management of the crop residues. In animal agriculture, feed is the major input cost, about 65-70 % of the total rearing cost (FAO, 2000).

1.1.3 Processing Technology

One of the main problems against the use of these residues is their storage, handling and application due to the low density of the material. The bulk density of biomass increases with densification, thus increasing the transportation efficiency and increasing its competitiveness with high-cost animal feed. The investigation of densification method here is pelleting. There are several types of pelleting process,including extrusion, compression, freeze pelletisation, globulation and also balling (Supriyaet al., 2012).

In terms of physical properties of pellets, Kaliyan and Morey (2009) defined pellet quality in terms of the friability and strength of the pellets. Friability refers to the percentage of friable from the pellets. Strength is a measure of both the compressive resistance and impact. The assessment of these qualities can be tested to the pellets in the feed industry by several established methods originally developed by the researcher (Kaliyan and Morey, 2009). These methods have been created to simulate the forces influenced on the pellets in the handling process and storage. As pellets are transported from production to utilisation, the level of pellets breakages are measured, and the results are used as indicators in handling and storage. The densification of biomass in industry may gain perception and understanding into densification behaviour. This is important research as the industry looks to expand to natural substances as feedstock beyond wood and plant material. Conversion of material into pellet form can improve efficiency in animal feed due to heat processing which reduces pathogens and make it more digestible for the animals. Furthermore, the advantages of pellets include the reduction in waste, reduction in segregation, improving palatability and allowing larger meals to be eaten in less time for the animals (Winowiski, 1995).

1.1.4 Nutritional Value

In terms of the nutritional value of the feedstock, the pellet must contain an adequate nutritional value for herbivorous feeding. The improper combination of moisture and heat may influence the structural integrity of a feedstuff and the nutritional content of the pellet being produced. Subsequent research has asserted that the addition of moisture during pelleting may have negative impacts, for example, including more weight per volume of feed, therefore expanding cost of transportation (Cutlip et al. 2008). Scientists Moritz et al. (2001) found that the addition of moisture at the blending stage had a tendency to improve pellet toughness and diminishing pellet mill energy utilization as a consequence of the added lubrication at the die. In spite of moisture addition results, the capacity to increase feed moisture through the pelleting process is reliant on encompassing atmospheric conditions, and in addition the nutrient composition of the diet. Current understanding of the pellet processing variables and moisture conditions is uncertain, consequently requiring more research in the field of feed manufacture.

Over the past three decades, local researchers have reported on the availability, nutritive value, optimal adding levels and treatment methods to enhance feeding values of many locally available feed ingredients in the herbivore food sector. These include evaluation and utilisation of the various agricultural by-products and crop residues from the oil palm industry, rice and other minor plantation industries. Recently, many animal-feed industries use waste from palm oil by-products as the source for cattle feed, including palm oil cake (PKC), palm press fibres (PPF), empty fruit bunches (EFB), palm oil mill effluent (POME) and oil palm fronds (OPF) (Wan Zahari and Wong, 2009). However, palm oil by-products are quite expensive although it is abundant in the palm oil industries.

1.1.5 Quality and Commercialisation of Pellet

Quality of the pellet is mostly a function of the type of process parameters and feedstock. By using different technique of pellet processing, this work is focusing on the effect of the different moisture content on pineapple waste fibre pellets in terms of physical and chemical content. One of the key parameter in the densification process is moisture. By investigating the pelleting process, the best pellet can be produced in terms of strong physical properties and also contain high nutritional value for herbivore consumption.

Table 1.1: Nutritional content of pelleted feeds from agricultural by-products (ABP).

Agricultural By-Products (ABP)	Dry Matter (%)	Crude Protein (%)	Ether Extract (%)	Crude Fibre (%)	Ash (%)	Neutral Detergent Fibre (%)	Acid Detergent Fibre (%)
Palm Press Fibre	94.5	4.3	21.0	36.4	9.0	84.5	69.3
Oil Palm Frond	34.9	7.0	2.4	32.3	5.0	78.7	53.6
Coffee Pulp	90.8	10.0	2.2	29.7	8.8	36.8	27.6
Pineapple Press	14.8	7.1	1.2	25.5	4.5	45.0	20.8
Rice Straw	88.7	4.2	1.2	30.4	18.4	72.5	43.2
Sago Pith	89.3	3.1	0.6	6.3	4.5	23.3	10.1
Plantain Peels	16.3	7.6	1.5	Not Available	5.7	47.2	28.6

Source: Dahlan Ismail, 2013

The Table 1.1 showed the nutritional content of various feeds from ABP. Utilisation of ABP as livestock feedtsuffs is an important strategy to reduce cost as the feeding cost is about 70% of production cost in intensive feeding management. The listed ABP in the table 1.1 can be selected for herbivores consumption based on the availability, nutrient content, and price of the material. From the table above, coffee pulp shows the highest crude protein, which is 10% and followed by plantain peels, 7.6% of crude protein, respectively. It shows that both of them are suitable for high protein intake for herbivores. The palm press fibre, shows the highest crude fibre, which is 36.4%, followed by oil palm frond, 32.3%. So, both of these feeds can be considered can be used to replace green grass in herbivorous feeding since it contain high crude fibre.

The utilization of the ABP, especially oil palm frond, palm press fibre, pineapple waste and other crop residues may provide a new feeding stuff for the livestock feed industry especially for herbivores in the tropical country. By having a huge amount of cheaper source of livestock feedstuffs from agricultural industrial crops, the cost of production and also the dependency on grazing areas can be minimized and support the developments of livestock production.

In Malaysia, pellets commercialisation is derived from oil palm by-products such as palm kernel cake (PKC), oil palm frond (OPF) and palm oil mill effluent (POME). They are often utilised as the main components in the feeds formulation. New approaches have been developed to improve the quality of the raw materials and finished products. Apart from making use of locally available ingredients to reduce cost of production, attempts have been made to produce more value-added feeds aiming at improving overall digestive system, growth performances and health status of the herbivores. One of the main issues related to consumer preferences, is the continuous demand for "high quality-low cost" feeds, which is a major challenge when agricultural-by products are used in feed manufacturing (Wan Zahari and Mohd Farid, 2011).

1.2 Problem Statement

Agro-waste is abundant and widely available around the world. It is produced during processing and harvesting activities (Shahzad et al. 2010).Malaysia has around 4.06 million hectares of agricultural land distributed throughout 14 states(Frost and Whitepepper, 2009). Currently, there are17,601 hectares of land that are being used to plant pineapples and about 334,400 metric tonnes of pineapple fruit were harvested in 2012 (FAO, 2014). Malaysia is the only country in the world that is growing pineapple mainly on peat soil (Ahmed et al. 2001). Agro-waste, which is the residue that is produced during processing or harvesting activities is disposed of and serves as a fertiliser or is burnt in the open field (Wan and Zainuddin, 2009).Open burning often involve of burning dead and living vegetation in the field (Koppmann et al. 2005). It has been evaluated by Streets et al. (2003) that on a yearly normal basis about 73,000,0000 metric tonnes amounts of biomass are being blazed in Asia, which 25,000,0000 metric tonnes is emerge from agricultural burning.Humans began to burn crop residues in order to set up new crops, remove agricultural wastes, control weeds and remove nutrients. Open burning is often done illegally when time is too short to open the field for new plantation. Now, open burning of most crop residues including pineapple has been banned because of ecological air quality contemplations (Environmental Quality Regulations 1974 corrected in 1998). Non-compliance to this act will acquire a punishment of RM 100,000.00.

The closest alternative to the burning of pineapple residues is the in-situ decomposition of the residues. However, some part of pineapple plant residue is served as fertiliser after furrowed into the soil, and ready for the next cycle of crop. However, the building or piling up of the mostly disintegrated residues takes not less 13 months or more before the disintegration or decomposition of these buildups happens (Ahmed et al. 2002). During the next crop, soil moisture content or soil wetness affect the rate of the anaerobic decomposition, which influences the amount of CH_4 discharged from this procedure. In spite of the fact that the consolidation of pineapple plant residue in the soil can give a wellspring of adequate nutrients to the following crop, it will exposed the next plant to the crop diseases (Hrynchuk, 1998) and regularly influences products from the soil. According to Buresh and Sayre (2007), the nitrogen immobilization will give transient negative impact to the next crops. So, open field burning is frequently practiced for disposal of pineapple plant residues because of this reason. It has been observed that open burning of crop residues additionally helps emanations of destructive air toxins, which can result in serious effects on human wellbeing. Korenaga et al. (2001) noted that a toxic gas will appear after such combustion such as polycyclic aromatic hydrocarbons (PAHs) and additionally polychlorinated dibenzo -p -dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), referred to as dioxins (Gullett and Touati, 2003; Lin et al, 2007). These pollutions are characterized by critical toxicological air and are eminentlypotential cancer causing agents. Air contamination not only affects human welfare and the environment, but have implications for the economy (Meesubkwang, 2007).

In order to contribute to addressing the above mentioned issues, conversion of these residues into value added products that have commercial use is crucial. An innovative or noble approach along this line will not only help generate additional income, but also create job opportunities (Ahmed et al. 2002).Recently, animal-feed production has become a new industry. The utilisation of agro-industrial wastes as animal-feed can reduce the worldwide agro-waste that is increasing every year. Poor nutrition of animals has been recognized as the significant effect to animal production over the world (FAO, 2000). For a variety of reasons, the tropical world is generally confronted with the issue of an intense deficiency of feed resources. With an extensive population of animal to feed, the feed shortage is become more crucial since there is lack of green forage production and failure in managing the degraded and unmanaged pastures.

There are numerous studies done by researchers on various aspects of pineapple wastes. Several authors analyzed the properties of pineapple wastes included physical, mechanical, and chemical properties from various pineapple varieties (Mohamed et al., 2009).However, the utilisation of agro-industrial wastes as animal feed seems to mitigate the difficulties of forage shortage during critical seasons. Several studies havefocused on exploiting pineapple wastes as feed for ruminants. The outer peel or skin and core from the pineapple canning industries, called bran, and the leaves are being utilized as feed for ruminants (Tran, 2006). The nutritive value of pineapple peel has been reported (Negesse et al., 2009). In China, pineapple waste from the field or from the cannery are being used as dairy feed (Sruamisri, 2007). Cattle preferred fermented pineapple waste with higher acidity to fresh waste. Dried and ensiled pineapple waste can be used as supplemental roughage and could replace 50% roughage in the total mixed ration for dairy cattle(Sruamisri, 2007). Besides, researchers have also focused on the performance and the apparent digestibility of pineapple by-product when used as feed. On feeding twenty four cross bred local goats for 80 days, it was found that dehydrated pineapple by-products would increase the digestibility with increase in weight of the animals (Costa et al., 2007).A survey reports that in Nigeria, pineapple waste are also used for feeding small ruminants and that they could be used after proper processing (Onwuka et al., 1997).If novel scientific and technological methods are applied, valuable products from pineapple wastes could be obtained.In this regard, cheap substrates, such as pineapple wastes have promising prospect. Thus, environmentally polluting by-products could be converted into products with a higher economic value than the main product. However, a suitable method and strategy of feed processing must be apply in order to minimise the cost of production and also to produce a consumable product by animal.

One of the available strategies is to develop a new system by densification of the biomass to provide better quality and to improve the feeding system. The densification can be processes in many ways, which include pelletisation technique. Recently, scientists have been interested in pelleting local feed resources and agricultural crop residues, such as mangosteen peel, pineapple waste, mulberry, sweet potato, and also from palm oil by products, to improve the nutritive value and its utilization. The technique involves are extrusion and compaction process. Both of processing technique, involve main parameters, which is binder. The binder additives may be used to improve the strength and shelf-life of pellets and to reduce the release of fines during the pelleting process. Preferably, magnesium, calcium, potassium and sulfur are used as the nutritive binder additives to the feed (Wanapat et al., 2013).However, the binder would be costly and the high fibre material itself already contain lignin, which act as a natural binder. With the help of moisture, it will increase the bonding of lignin within the pellets. The variation or technique in producing and processing the pellets need to be identify. However, there is no detail of report on comparison between extrusion and compaction technique in making pellets from the pineapple plant waste.

In Malaysia, overgrazing is a typical issue prompting to rapid degradation of the pastures. Extreme consumption of soil nutrients is an alternate basic issue as there is no proper management to beat the issue (Chin, 1998).Thus, there is a need to create a new alternative to replace pastures and grazing forages for herbivores. Inappropriate management of feed resources, particularly of fibrous and bulky yield residues, is another component contributing to low productivity of herbivores and animals in the tropics. Enhancing the management of crop residues as animal feed and confining its wastage through burning, ought to be one of the fundamental needs. In this way, there is a critical need to upgrade the utilisation of the limited feed resources, particularly pineapple plant residue for feeding herbivores and livestocks.

In terms of economics, the livestock industry will boost the economy through this strategy by improving the feeding system. Profitability to farmers is improved as there will be improved nutrition for their animals resulting about expanded animal productivity and better animal performance. This thusly enhances the level of income of the ranchers and lifts their societal position in their community.

In conclusion, plant fibrous waste materials such as pineapple plant waste (PPW) need to be utilised properly in order to avoid disposal problems especially burning activities which can contribute to the haze problem in the tropical areas. Through proper processing technology, these fibrous materials can be converted into an herbivorous fibre feed source. This approach will be more economical in the feed industry and also be environmentally friendly.

1.3 Objectives

The objectives of this study are:

i) To evaluate the physico-chemical properties of whole pineapple plant waste (PPW) varieties.
ii) To develop the pelletising process of pineapple plant waste (PPW) for the manufacture of herbivore feed by using an extrusion and a compaction process.
iii) To investigate the digestibility of pineapple plant waste (PPW) pellets by using an *in vitro* technique.

1.4 Hypothesis

In Malaysia, there is no standard CIP process that was formulated for all food industries. Most of the food industries applied the standard CIP process designed for dairy-based fouling deposit. Every type of food-based fouling deposit requires a different formulated CIP process to achieve effective cleaning. Short CIP process is favorable to food industries as food industries incur downtime when cleaning is performed. Thorough investigation of CIP performance on different fouling deposits is a must to obtain effective and economical cleaning.

1.5 Scope of Work

The study focused on the feed processing technique regarding to the pelletisation process, which is being implemented for herbivores consumption. Pelleted feeds have been used successfully for animals including herbivores, fish and shrimp. This study is interested on making the pellet from agricultural product, which is pineapple plant waste, as the raw material. Generally, the pelletisation process involving engineering processing such as chopping, milling, grinding, drying and pelletising by using extruder and compacter. Both of extruder and compacter are used for pelletising purpose, but work in different ways. Pelleted feeds are produced in an extrusion-type thermoplastic melding operation, which is called as extruder. Another tools is meat mincer, which is used as compacter for pineapple plant waste, which it give different ways of processing. Heat, pressure, screw speed from extruder can be control, but not for the meat mincer. However, the raw materials need 30% and above of moisture content in order to run the process. This somehow will give differences in pellets productions in terms of shapes, rigidity, and also cost of production. This study would also like to know the nutritional content of both of the pellets different processing and also the digestibility of the pellets in the ruminants.

1.6 Organisation of Thesis

This thesis is organised in five chapters, which include introduction, literature review, materials and methods, results and discussion, conclusion and recommendations for future work. In the Introductory chapter, a general introduction to pineapples and pineapple waste in the field is given, including a discussion of the potential to use as feed material. The Literature Review chapter presents details of the agricultural waste, focusing on pineapple waste, which is to be used to produce feed for herbivores, and the background of the processing method is given. The chemical and physical properties of the different types of biomass, as well as the processing parameters affecting the pelleting process, namely the moisture content of material, is discussed. Finally, the densified products and digestibility of the pellets are reviewed.

In the Materials and Methods chapter, the methods followed and the equipment used to measure the physical and chemical properties, and the digestibility of the pellets are described. In the Result and Discussions chapter, the experimental results obtained for the physical and chemical composition of the raw materials are presented and interpreted. Lastly, the Conclusions are followed by Recommendations for Future Work, which addresses issues that could be considered in future studies.

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