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INAUGURAL LECTURE

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Challenges in Feeding Livestock: From Wastes to Feed

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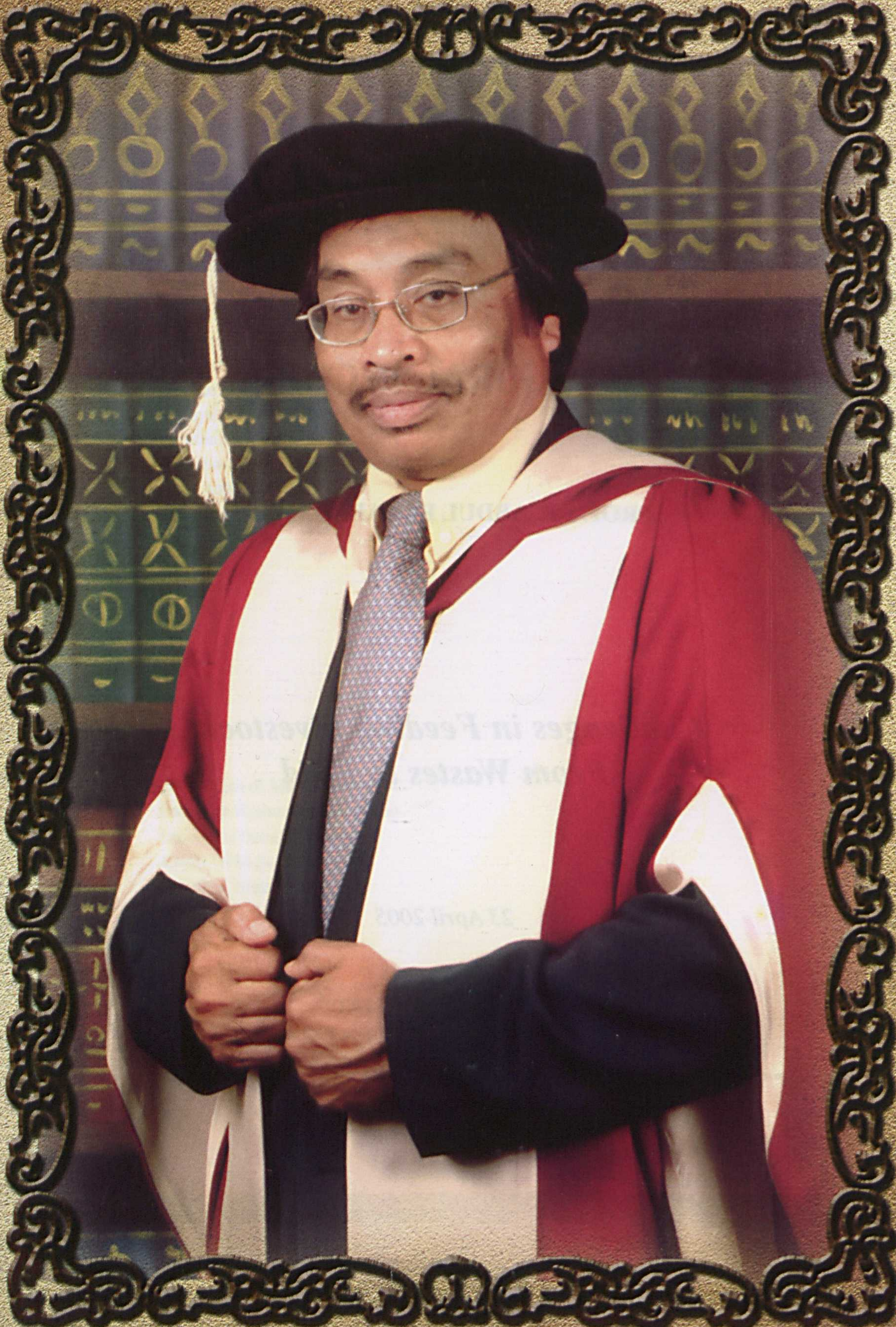

ABDUL RAZAK ALIMON

Professor Abdul Razak Alimon was born in Merlimau, Melaka. He obtained his early education at Merlimau English School, his secondary schooling at Jasin Secondary English School (now known as Sekolah Dato Bendahara) and at Malacca High School. After his Cambridge High School Certificate Examinations, he was offered a Colombo Plan Scholarship to study in Australia, at the University of New England Armidale N.S.W. Australia. He obtained my Bachelor of Science degree (1972), and Post-graduate Diploma in Science in Agriculture (1973) and Masters of Science in Agriculture (1980), in the field of Animal Nutrition. Later, in 1989 he obtained his PhD from the University of Reading, United Kingdom.

He was appointed lecturer in February 1980, promoted to Associate Professor in 1995 and Professor early 2004. As a lecturer at the Department of Animal Science, Faculty of Agriculture, he taught Animal Nutrition, Animal Production and other related subjects. During his teaching career he had supervised or co-supervised more than 10 Ph.D. students, and more than 20 Masters students. Most of these students were from foreign countries such as Indonesia, Thailand, Bangladesh, Myanmar, Iraq, China, Yemen, Iran and Palestine. On the administrative side, Professor Abdul Razak was appointed as Master of Third college (now known as Kolej Tun Dr Ismail) from 1984-1985, and currently Master of Kolej Mohammad Rashid since 1996.

Professor Abdul Razak is a member of various professional societies, such as the Malaysian Society of Animal Production, Malaysian Nutrition Society, Malaysian Zoological Society (MZS). In the MZS he serves in the Council that governs the running and administration of Malaysian National Zoo (Zoo Negara) since 1992. He is currently Vice Chairman of the Executive Management Committee and Vice President of the Council. He has been a member of the animal welfare committee (AWC) for MZS and also for SEAZA (South East Asian Zoo Association). General Secretary for Malaysian Society of Animal Production (MSAP) from 2000 to 2004, and also in the editorial board for the journal published by MSAP, The Malaysian Journal of Animal Science. Internationally, Professor Abdul Razak has been in the Steering Committee for 1st and 2nd ISTAP (Indonesia) conference held every two years, and a member of the editorial board for the Indonesian journal *Buletin Penternakan* for a number of years.

He has been awarded several fellowships to carry out research and study tours. Under the IAEA fellowship scheme he was given the opportunity to work with Dr. Mike Ivan, a prominent scientist at Agriculture Canada, in Ottawa for 3 months in 1994. Under the JSPS fellowship scheme he was selected to spend time at Hiroshima University in 1995, and worked with Prof. Toshio Ito and Prof. Yamamoto in the field of nutritional physiology. In 2003 he was again selected, under JSPS fellowship scheme, to visit Tsukuba University and had the opportunity to work with Professor Yukio Kanai. He has been awarded excellent service awards at faculty and university levels. In 1999 he was awarded the excellent service award by the University and at faculty, several times, i.e. in 1997, 1998, 2000 and 2001. Again in 2002, he was awarded excellent service by the Student Affairs Division, UPM for my services as head of college. In 1997, the state of Melaka awarded him the Bintang Cemerlang Melaka (Excellent Service Award Melaka State) for services to the university and the country.

Professor Abdul Razak is married with two children, the eldest is a graduate in food science, and the second child is pursuing a degree in computer science, both at UPM.

CHALLENGES IN FEEDING LIVESTOCK: FROM WASTES TO FEED

ABSTRACT

The livestock industry is highly dependent on available and cheap feedstuff. Competition between man and animal for the same food is increasing. Subsequently, the search for alternatives to feed livestock must go on. Waste materials from agro-industry are possible alternatives to the traditional feedstuffs which are continuously increasing in price and scarsity. This paper discusses some of the methods and possible ways of using wastes products from the agricultural sector. Materials like rice straw has been used as animal feed but its use is declining. Many rice farmers no longer keep buffaloes or cattle and therefore the need to use the straw is diminishing. Palm byproducts, such as palm kernel cake, are useful and contribute towards the country's foreign exchange. About 1.7 million tonnes of palm kernel cake is exported annually bringing an income of about RM400 million. However, the livestock industry is deprived of the palm kernel cake which if used locally can support more than half a million heads of cattle. Other byproducts such as rice straw, palm fronds, rice bran and corn stover are not produced in such large quantities, but if the process of collecting and processing to improve their quality can be consolidated as a viable industry much of the feed imports can be reduced. Newer technologies need to be developed with considerations of reducing labour and related costs in the methods of collecting, processing, storage and distribution.

INTRODUCTION

The cost of feeding the human population is increasing enormously day by day in Malaysia. As the standard of living increases and changing lifestyles so is the choice and the willingness to pay for food. The food that we eat undoubtedly comes from both plants and animals. Animal products such as dairy foods, meat, eggs, and fish constitute a major portion of our food bill. However, much of our meat, milk and milk products are imported because our own production cannot meet the increasing demand. In total Malaysia imports on food is more than 13 billion ringgit a year.

LIVESTOCK PRODUCTION IN MALAYSIA

The poultry industry in Malaysia is well developed and supply almost 100% of the country needs for poultry meat and eggs. Similarly, the swine industry is fast growing and Malaysia is self sufficient in pork. On the other hand, the ruminant industry is less developed and is largely in the hands of smallholder farmers throughout the country. Malaysia still imports more than 80% of beef and mutton and milk products. There are very few large farms available possibly because of high investments and poor returns. Furthermore, arable land for traditional grazing is scarse and is usually cultivated for the more profitable plantation crops.

FARMING SYSTEMS IN MALAYSIA

The farming system adopted by pig and poultry farmers is usually fully intensive and quite often in a closed house system, whereby compounded feed are given to these animals. Almost all of the feed ingredients are imported and this industry is highly competitive. While imported feedstuffs are expensive they are essential for the growth of pig and poultry industry and as such the profit margins in such enterprises are often small. Subsequently, only farmers that are efficient and those with a large scale of production survive.

The cattle, goat and sheep farms are mainly in the hands of smallholder farmers. The systems of production practiced by these farmers generally vary from extensive, semi intensive to fully intensive. While, large farms practicing fully intensive system exists, their numbers are small but are slowly increasing in numbers. The development of the ruminant industry depends, among other things, on the availability and price of feed. The smallholder farmers still constitute a large proportion of the ruminant farmers mostly practicing the extensive or semi intensive farming systems. The main feed resource of animals under smallholder system comprised of native pasture available on these waste lands and are either grazed or fed cut and carry. In the smallholder system the animals are often supplemented with some form of protein and energy sources such as cut grass, palm kernel cake, soya waste, brewers spent grain and bakery wastes.

Beef cattle raised in feedlots (fully intensive system) are usually fed compounded rations such as a mixture of palm kernel cake, rice bran, corn gluten meal supplemented with minerals and vitamins. The main problem associated with feedlot production is the availability of reasonably cheap feed. Similarly, sheep and goat farmers are also facing the same problems. Imports of live animals for breeding purposes or slaughter have been increasing in the last decade.

STATUS OF FEED PRODUCTION IN MALAYSIA

Malaysia does not produce much raw ingredients for animal feed. Small amounts of rice bran, soya bean meal, wheat bran and pollard, maize gluten meal and other milling by-products, are produced locally as by-products of grain milling and soya bean processing. Wheat, corn flour and rice milling industries are not large enough to provide sufficient by-products to accommodate the amount required by the livestock industry. Other by-products such as tapioca chips and fish meal are also produced in small quantities. As such Malaysia still imports feedstuffs to the value of above RM2.0 billion annually, to supplement those produced locally.

Palm kernel meal, commonly known as palm kernel cake, or PKC in short, is about the only feedstuff which is produced in significantly large quantities in Malaysia. It is a by-product obtained after the extraction of oil from oil palm kernels. Malaysia produces about 2.0 million tonnes of PKC annually, but about 80% are exported. Inevitably, the local price of PKC is somewhat dependent on world market price, especially the Rotterdam market price. The majority of Malaysian PKC find its way into The Netherlands, Germany and other European countries. A small percentage is also exported to Japan, South Korea and China.

From rice growing activities broken rice and rice bran are produced. Both broken rice and rice bran are common ingredients in poultry and pigs rations. Although rice bran produced locally especially by small millers is generally not defatted and therefore poses a problem in terms of shelf life it is widely used by small holder farmers for feeding their livestock including free range poultry.

The feedstuffs imported into Malaysia come from many different countries. For example, maize is imported into Malaysia from countries as far as United States, Canada and Argentina and also from countries closer such as Indonesia, Thailand and Vietnam.

Unlike many countries in South East Asia, Malaysia does not produce cereal grains for animal feed. Rice, which is the staple food of Malaysians, is grown mainly for human consumption and the by-products such as rice bran and broken rice are utilized for animal feed. Grain maize is not widely grown in Malaysia. Because of the hot and humid conditions maize produced in Malaysia are easily contaminated with moulds and need to be screened for mycotoxins before it can be safely used in animal feeds. Furthermore, the returns from grain maize growing activity are low and not competitive enough to attract investors. In the 1970s large areas of land were grown with tapioca for starch extraction and also for the production of tapioca chips for animal feeds. Malaysian climatic condition allowed tapioca to grow well and was considered to be potentially a viable industry. However, with increasing lack of arable land and high costs of labour the production of tapioca has been mainly for starch extraction and has been declining. Malaysia currently imports tapioca from Thailand for animal feeds.

Maize gluten meal is produced in some quantities as a by-product of maize grain milling to obtain maize flour or maize starch. Similarly, wheat by-products are obtained from wheat milling for flour. Production of wheat by-products, such as wheat germ meal, wheat middlings and wheat bran, are increasing due to increasing importations of wheat for flour production. Wheat is imported from Canada, USA and Australia. While these by-products can be used as animal feed they are also used in breakfast cereals for humans.

As far as protein sources are concerned some soya bean meal is produced as a by-product of processing the beans for the extraction of oil. Like wheat, soya bean is not produced in Malaysia and is mostly imported. Extraction of oil from soya bean and the production of soya bean curd and drinks produce soya bean by-products such as soya bean meal, soya bean waste and soya bean hulls. The fish meal industry is small and depends on available waste or trash fish and supplies 10-15% of the country's requirements. As such, the quantity and quality of fish meal produced tends to be irregular fluctuates according to season and type of fish obtained. The protein content averages 55% and is generally of poorer quality when compared to imported fishmeal as the ash content is high. The fish catch is Malaysia not large enough to support a large fish meal industry as well as for human consumption. Fishmeal which is produced from waste or trash fish and supplies only about 10-15% of the country's requirements. However, the main problem with locally produced fishmeal is its irregularity in supply and quality. With the continuous increase in demand for animal products, the demand for feed will be increasing. It is estimated that the requirement for animal feed will surpass 4.0 million tonnes by the year 2005.

SHOULD ANIMALS COMPETE WITH HUMANS FOR FOOD

Animals have to be fed to provide them with the necessary nutrients required for maintenance, growth and production. Nutrients required by animals are similar to that required by humans. They require energy source, protein, minerals and vitamins. It is well recognized that, for economic reasons, materials or feedstuffs that are fed to animals should preferably not be in competition with those consumed by humans. Nevertheless, many feed items that are included in the rations for animals do contain food items that in some instances compete with humans. For example, corn is grown not only for human consumption but also for animals. Perhaps, this is where many of us feel that food grown that can be used by humans should be given to humans as a matter of priority. The conversion efficiency of poultry for instance is about 2.00 kg per kg of weight gain, while that for cattle or buffaloes is about 6 kg per kg weight gain. It is and shall always be, more efficient to deliver the food directly to the consumer, rather than feeding animals and later consuming the animal products. When animals were first domesticated many thousand of years ago, they were fed food scraps and food wastes from the table or were allowed to roam and graze. But farming has since changed and commercial livestock production demands that livestock be fed easily available and nutritious feeds to support the fast growth rates and rapid production cycles. Farm size has also changed through the last century, from small holder farms having a few chickens to large commercial farms housing a few hundred thousand.

WHAT ARE WASTE PRODUCTS

Waste products are defined as materials that are left unused after the primary product has been extracted from the original material leaving behind residues which are also considered as a by-product. The residue or by-product may be useful for some other purposes or it can be reprocessed to become a value added product. For example, in the process of extracting oil from palm oil fruits, various by-products, such as palm pressed fibre, palm kernel cake, empty fruit bunches and palm nut shell, are produced. Some residues cannot be used and are discarded creating a problem to the environment. In livestock or poultry farming, wastes also include products that are excreted by animals and are generally disposed off or made into compost for fertilizer. Wastes from piggeries and feedlot farms which are usually in the form of slurries pollutes the rivers and streams if they are not treated before disposal. In the food industry wastes include products or by-products that arise from processing of the food products.

However, in some instances the by-products are no longer wastes an called co-products, as it is accepted the by-products are marketable for the purpose of livestock feed or other uses. A good example is when soyabean is pressed for oil the co-product, soya bean meal, is a high quality protein source and fetches a good price. In fact, nowadays soyabean is grown for the meal more than for the oil. Table 1 shows some of the waste or by-products that are produced in various types of industries.

AGRO-INDUSTRIAL BY-PRODUCTS

Agro industrial by-products (AIBP) are defined as a 'waste product' directly or indirectly produced after the harvesting or processing of agricultural products for the purpose of human consumption or industrial utilization. These by-products, being mostly organic in nature, are potentially useful sources of energy and/or nitrogen for animals.

Crop residues (CR) are defined as parts of crops or any products that remained after the main products for which the crop is grown has been collected. In the case of cereals crops the residues include straws, stubbles, maize cobs, and in the case of other crops such as soyabean, sweet potato, etc. leaves and twigs, vines, and other vegetative parts of the plants. In Malaysia several crop residues are available, and potentially useful as animal feed (Table 1), but sometimes are not used as feed because of economic reasons.

Table 1. Agro-industrial by-products (AIBP) produced in Malaysia.

Crops/product	By-products
Rice	rice bran, broken rice
Palm oil mills	Palm kernel cake, palm press fibre, POS
Maize	Maize gluten meal
Soyabean/oil	Soyabean meal, soyabean hull
Soyabean/curd/drinks	Soya waste
Barley/brewing	Brewers grain
Fisheries	fishmeal, trash fish, shrimp heads
Poultry	Poultry litter, poultry byproducts
Pineapple/canning	pineapple waste
Tapioca/starch	Tapioca waste
Sago/starch	Sago waste
Sugar cane/sugar	Bagasse, molasses
Wood industries	sawdust

Characteristics of Crop Residues (CR)

Table 2 shows the chemical composition of some CR. In general these materials contain more than 20% crude fibre. The crude fibre component include cellulose, hemicellulose, lignin and other complexes that are not easily digested by monogastrics. Because lignin is highly indigestible, as no enzymes in the rumen are able to digest the lignin, lignified feedstuffs tend to be poorly digested. Poor digestibility is also attributed to high NDF contents and also possibly the presence of one or more anti-nutritive factors. Poorly digested feed will show poor intakes, and subsequently the animal will not obtain enough energy or protein for growth. Many AIBP and CR contain anti-nutritional factors that could affect the intake and metabolism of the animals. Cottonseed meal for instance contain gossypol which can affect growth and productivity of chickens. Tapioca wastes may contain prussic acid, while cocoa pods may contain theobromine. Rice bran contain phytic acid which causes phosphorus to be bound and not absorbed or utilized. Rice straw is high in silica content, which may, on the long run cause urinary calculi. Subsequently, CR tend to be less palatable and poorly accepted by animals. It must be noted that CR are only suitable for ruminants, while non-ruminants are not able to utilize most of these materials. Other than that, they contain poor amounts of crude protein and vitamins.

Table 2: Composition (%) of some AIBP and CR (based on Dry Matter).

	CP	Ash	EE	CF	ME (MJ/kg)
Palm Kernel Cake	16 - 18	3 - 4	4 - 6	14 - 16	9.97
Palm Press Fibre	4 - 5	8 -15	16 - 21	30 - 37	3.97
Palm Oil Sludge	9 -14	11 - 26	11-21	11- 24	6.50
Oil Palm Fronds	9 -15	3 - 4	4-5	21- 43	6.0 - 7.0
Brewers grain	20 - 23	4 - 5	6-7	15 - 16	10.4- 10.6
Pineapple waste	5 - 7	4 - 8	0.5-1.0	10 - 18	11.52
Tapioca waste	1 - 2	2 - 3	1 - 2	9 - 13	10.29
Sago waste	1.5	3 - 5	2 - 3	10 -15	12.32
Rice bran	14.1	12.8	4.9	12.0	8.84
Rice straw	4.2	18.4	1.2	30.4	4.97
Sugarcane tops	4-6	8 - 11	2 - 4	31 - 38	8.4 - 8.7
Cocoa pods	4-6	3 -6	4 -6	31 - 35	6.0 - 7.0

MONOGASTRICS AND RUMINANTS

Monogastrics are animals that have a simple stomach, such as poultry, pig, rabbits and ostrich. They are also called simple-stomached animals. Their feed comprised of concentrate feed are not able to tolerate highly fibrous food. Ruminants on the other hand, have a complex stomach which comprise of rumen, reticulum, omasum and abomasums. Examples of ruminant animals are cattle, sheep, goats and buffaloes. Ruminant animals have the ability to digest fibrous materials and therefore they are generally herbivores. The abomasum is the true stomach of ruminants while the reticulum and rumen is like a large fermentation vat containing millions of bacteria and protozoa which are able to digest and degrade fibrous materials to products that can be utilized by the host animal. The anaerobic bacteria and protozoa produces enzymes that act on the complex carbohydrates or polysaccharides to produce simple sugars and fatty acids. These sugars together with nitrogen sources are then utilized to form bacterial and protozoal protein and other carbohydrates which later on will be digested by the host enzymes in the abomasums and small intestines. The by-products of fermentation include volatile fatty acids which can be absorbed directly through the rumen wall and utilized as a source of energy, microbial protein and ammonia. One unique quality of ruminants is that they are able to utilize non protein nitrogen (NPN) such as urea, uric acid and biuret. Bacteria and protozoa convert NPN to amino acids for their own use. Therefore, when protein is in short supply NPN can be included in the diet to improve its crude protein content. However, the amounts that is tolerable is between 3 - 5% of dry matter. Higher than this the urea will be converted to ammonia or will be absorbed at high rates to cause urea poisoning.

Ruminants are important animals in the ecosystem, in that they are able to utilize wastes that are fibrous in nature. In Malaysia, cattle, buffaloes, sheep and goats have been fed wastes such rice straw, oil palm fronds, palm oil sludge and corn stover.

THE ROLE OF AIBP AND CR IN RUMINANT RATIONS

A pressing problem faced by ruminant farmers is the availability of cheap and reasonable quality feedstuffs. This is because pasture is no longer readily available and many farmers are turning to using agro industrial by-products (AIBP) and crop residues (CR) to replace pasture. Malaysia produces large quantities of agro-industrial by-products, such as palm press fibre, empty fruit bunches, rice straw, much of which is too fibrous to be used as feed. AIBP and CR are generally low in crude protein content, high in crude fibre and consequently poorly digested. In some instances these by-products supply energy at amounts barely sufficient to meet the requirements for maintenance. Nevertheless, these materials are useful and can be efficiently utilized if they are treated either physically or chemically to increase its palatability and digestibility. The nutritive value of these by-products and crop residues can be improved through various physical and chemical treatments. Research in Malaysia on agro-industrial by-products and crop residues are still on-going. Chemicals that have been tested include urea and sodium hydroxide treatment, ensiling, chopping and fungal treatment. A summary of the results on intake and digestibility values is shown in Table 3.

Table 3. Summary of techniques in improving the nutritive value of AIBP and CR in Malaysia.

Products	Treatment	Effect	Reference
Palm press fibre	urea	+ DMD	
Empty fruit bunches	chemical	+ DMD	
Oil palm fronds	ensiling	+ intake	
	pelleting	+ DMD, intake	
Oil palm trunks	ensiling	+ intake	
Rice straw	chop	+ intake	
	urea	+ DMD	
	NaOH	+ DMD	
	CaOH	+ DMD	
	Fungal	+ DMD	
Maize stovers	chopping,	+ intake	
	ensiling	+ DMD, intake	
Cocoa pods	fungal	+ DMD	
	Urea	+ intake	
Pineapple wastes	ensiling	+ intake	
Soyabean waste	drying	+ intake	
Tapioca waste	drying	+intake	
	fungal	+DMD	

(+), increased; DMD, dry matter digestibility

PROCESSING OF AIBP AND CR

One way of improving the nutritive value of waste products is by treating the materials with chemicals or by processing such as fermenting, or physical means. Treatment often increases the surface area for the actions of bacterial enzymes or dissolving the hard and insoluble lignin so that the cellulose can be exposed to the bacterial enzymes. Furthermore, through treatments or processing, the texture of the materials can be improved thereby improving its palatability. The common methods of treating AIBP and CR to improve their nutritive value are as follows:

Physical treatments

- Grinding, milling, chopping
- Steaming, heating, soaking, pelleting, autoclaving.

Chemical treatments

- treating with sodium hydroxide, potassium hydroxide, lime
- ammonia, ozone, hydrogen sulphide

Biological treatments

- fungal treatment
- solid state fermentation
- enzymes

OIL PALM BY-PRODUCTS

The oil palm crop has been hailed as the golden crop of Malaysia. From the palm were harvested its primary product namely, palm oil, from which a whole lot of by-products that has the potential to spur the livestock industry and also develop oleo-chemical industry. From the animal point of view, the oil palm provides roughages for energy source, and also palm kernel cake, a concentrate feed which is an energy and protein source. A variety of potential feedstuffs are obtained from the oil palm crop. From the plantation, the fronds removed during harvesting are potential roughage source for ruminant animals. It is high in cellulose and can be an energy source for sheep, goats, cattle and buffaloes. From the fruit, after the extraction of oil from the kernel a valuable by-product, palm kernel cake, is obtained. From a lowly beginning when it was considered as a waste and discarded, palm kernel cake is now a value added product much in demand as feed for cattle and small ruminants (Alimon and Yaakub, 2004). The following discusses some of the common by-products obtained from the oil palm tree.

Palm press fibre (PPF)

Obtained after the mesocarp of the oil palm fruit is pressed to remove its oil. It constitutes the largest part of the fruit that is discarded after oil extraction. It is highly fibrous and low in protein content. At present, it is little used for feeding ruminants but, at the mill, it is usually burned to provide fuel and a small percentage being used in mushroom production. Studies have shown that palm press fibre need to be treated with sodium hydroxide before it can be successfully included in ruminant diets.

Palm kernel cake (PKC)

PKC is obtained after the nutshell is cracked and the kernel pressed to remove its oil. This cake is a useful feed for ruminants because it contains about 16 - 18% crude protein, 16% crude fibre. In Malaysia, PKC has been successfully included in diets of cattle, buffaloes and small ruminants. With proper mineral and vitamin supplementation PKC can be fed at levels up to 95 per cent in rations for feedlot beef cattle. Growth rates of up to 1100 g/ day with beef cattle have been recorded. In dairy cow ration PKC has been included at more than 50% level to provide the energy and protein for milk production. However, with small ruminants inclusion of PKC at high levels may cause copper poisoning. Studies by Hair-Bejo and Alimon (1992a) indicated that the symptoms of the poisoning were observed to be similar to that of copper toxicity. Supplementing with 100 ppm of Zinc sulphate and/or ammonium molydate in the diet appeared to relieve the copper toxicity symptoms (Rusihan et al., 1997). Li Juan et al., (1998) confirmed that supplementation with ammonium molybdate and sodium sulphate reduced incidences of copper toxicity in sheep. Goats and sheep can tolerate up to 50% in the ration. It is not clearly understood how the copper reacts on the body systems. Studies by Hair Bejo and Alimon (1992a, 1992b) show that the lesions associated with copper poisoning appears to be similar to that with jaundice. Observations on the liver suggest liver damage. It is not clear whether breed of sheep has any effect on tolerance to copper, but in a more recent study Al-Kirshi et al (2003; 2004) and Al Waheidi (2004) showed that Santa Ines sheep did not come down with copper toxicity even though they were fed 90% PKC for six months, but the copper contents of the liver had levels higher than 800 ppm (Al Kirshi et al., 2004) It is known that in goats, toxicity appears much later than sheep although there is little documented evidence on this subject. PKC has also been fed to deer as a supplement and is well accepted. It has been established that the palm tree has the potential of accumulating copper in the fruits and leaves.

As far as large ruminants are concern, PKC appears to be a safe feed; providing sufficient crude protein and Metabolisable Energy for maintenance and growth. Problems of aflatoxins or other mycotoxins have not been reported, but because of the fat content of expeller extracted PKC there may be chances of mycotoxins appearing in PKC kept for long periods and under moist conditions.

Some twenty years ago, farmers were reluctant to include PKC in rations for poultry. This was because the high fibre content and poor amino acid availability was thought to depress growth and production. The protein content of about 16% is low for non-ruminants, while the lysine content of less than 2% makes it less valuable for poultry. Radim et al (1999) showed that PKC can replace 50% of the corn in layer diets without deleterious effects on egg production and quality. Earlier studies by Ukil et al (1999) showed that broiler chickens, after 2 weeks of age, can tolerate PKC up to 20%. In another study, Mustafa and Alimon (2003) concluded that PKC can be included at levels up to 25% without deleterious effects on Muscovy ducks, provided that lysine and methionine were supplemented to meet the requirements. Mustafa et al., (2003) showed that ducks are superior to broiler chickens in utilizing PKC. Studies on the morphology of ducks and chicks did not show significant changes in the structure of mucosal layer of small intestine. However, when the birds were young (3 weeks) there were variations in the villus height in the small intestines, but these changes were diminished when the birds were more than 6 weeks of age.

Palm oil mill effluent (POME)

Also known as palm oil sludge. This material which is obtained after partial drying of the solids that is reclaimed from retention ponds where waste water from the mill is collected. It contains particles of mesocarp and organic substance originating from the palm fruit. Therefore, it consists of some protein, fat and carbohydrate and can be included in livestock rations. However, its ash content is rather high (12- 20%). It has been shown that up to 15% can be included in poultry rations and up to 30% in cattle rations. A mixture of 30% PKC, 30% POME and 40% spent brewers grains become an ideal supplement for beef cattle. POME is usually marketed in the wet form with about 60-70% moisture. As such, the logistics of transport and handling restrict its use to farms within a reasonable distance from the palm oil factory. It cannot be incorporated in greater proportion in non-ruminant rations because of its high content of ash and copper. Presently, oil palm mills collect and process POME into fertilizer.

Oil palm fronds (OPF)

Recently studies by scientists at MARDI have indicated that oil palm fronds can be a suitable source of roughage for beef cattle. MARDI has embarked into a program looking at the various methods of treating and processing OPF to improve its nutritive value. By chopping and ensiling and supplementing with protein sources, OPF have been shown to be a suitable source of energy for growing cattle (Ishida et al., 1994). MARDI together with their Japanese counterparts (JICA) have set up a pilot plant to process OPF into what is called OPF cubes or pellets and also OPF TMR(Total Mixed Ration). Their studies demonstrated that OPF could be a potential feed source for beef and dairy cattle. The OPF TMR can be used as a complete ration for beef cattle with average daily gains of 800 - 1100g per day (Wan Zahari and Alimon, 2004).

Oil Palm Trunk (OPT)

Oil palm trunks are obtained when the trees are chopped down at the end of their production, usually about 20 - 25 years. Oil palm trunks are not suitable for timber and alternative uses of the trunks are currently being investigated in Malaysia. In early 1990s MARDI embarked on a research programme looking into the possibility of using the trunks as sources of energy for ruminants (Abu Hassan and Azizan, 1991). OPT has been chopped, chipped, treated with NaOH and ensiled. It appears that OPT can be used as a source of fibre for ruminants though not as the main source of energy. The high costs of processing may prohibit it from being widely used as animal feed. In fact more work now is conducted on its use as a composite material for the building and manufacturing industry.

Palm Oil By-products

PFAD or palm fatty acid distillates are obtained during the refining of palm oil. PFAD has been used in animal diets as a source of energy but its use is limited to a maximum of about 10% in the rations. As an energy source it provides about 38MJ/kg ME. Value added products has been manufactured using PFAD. Fatty acids when combined with calcium form calcium salt which has been marketed as an energy supplement. Calcium salt of fatty acids can be fed to dairy cattle at levels higher than 10%. This is because in the salt form fatty acid is not attacked by rumen bacteria and therefore spared the fermentation process. In the abomasum the calcium salts of fatty acids are digested and made available to the animal (Palmquist, 2004). Studies in our laboratory show that calcium salts of crude palm oil and calcium salts of PFAD acid were equally good in supporting growth and performance of goats (Al-Waheidi et al., 2004).

Another product that has been investigated is the oil extracted from bleaching earth. Bleaching earth is used as a clarification agent in palm oil refining. As much as 20% oil can be extracted from spent bleaching earth but it is not used for human consumption. Studies have shown that this residue can be included in poultry rations at levels of about 4%. The TME content determined using the Sibbald method was about 35 MJ/kg. In a feeding trial, diets containing recovered oil was compared those with CPO and a control diet. The results showed that there was no difference in the performance of broilers when compared to the controls (Manvi and Alimon, 2003).

RICE BY-PRODUCTS

By-products from the rice industry include rice straw, rice bran and broken rice. Rice straw is the residue left after the rice grain (padi) is harvested from the field leaving rice straw and stubbles. The rice straw includes the stem, leaves and grain stalks. Like other cereal straws, e.g. barley, wheat, sorghum, rice straw can and is commonly used as feed for small and large ruminants. In Thailand, Indonesia, India and Sri Lanka, rice straw is either fed directly to animals or treated with urea or alkali. The quality of the straw is very dependent on the variety, soil types and fertilization rates. Rice husk is obtained after rice grain is removed of its hull to obtain the rice. It is unpalatable to most livestock and is seldom included in animal ration. It is high in silica and lignin rendering indigestible. Attempts have been made to treat the husks with chemicals to remove its silica and improve its digestibility. However, little success has been achieved in utilizing rice husks as feed and other industrial uses of rice husks are being investigated.

Rice bran

Rice milling involves removing of the hull followed by polishing the grain to achieve its white colour. The rice polishing is also called rice bran and include the aleurone layer of the seed and the germ. However, rice hulls can also be included in the rice bran especially when the milling does not remove the hull completely. Therefore the quality of rice bran is also dependent on the amount of contamination by the hull, such that the higher the hull content the lower is the nutritive value. Typically, there are two types of rice bran, those that are not defatted (full fat rice bran) and defatted rice bran. Defatted rice bran is the one that has been pressed for oil and is slightly low in energy because of the low (1-2%) oil content. Within this too, there are many different grades of rice bran pending on the contents of hulls and other materials.

Rice bran is a much sought after commodity because of its low cost and high palatability for both ruminant and non-ruminant. It is a good source of energy and to some extent, protein. Its chemical composition is shown in Table 6. Oil extracted rice bran fetch a better price because of its keeping quality and is commonly included in poultry rations. In poultry ration it is included at levels of 10 - 15% but in dairy and beef cattle rations it can be included up to 40%.

Rice bran for poultry

Rice bran is traditionally a by product of the rice milling industry and has been used as an ingredient in poultry rations. But due to its high fibre content (12-14%) its use in poultry rations is limited. Traditionally 10 - 15% is included in rations, higher than this can cause reduction in growth and poor FCR. While its energy content is reasonably high for poultry it has been shown that rice bran contain an anti-nutritive factor known as phytic acid (Ukil and Alimon, 1998), Phytic acid combines with metal ions and form complexes render some minerals unavailable. Phosphorus tend to be more affected as most of phosphorus found in cereal grains are in this complex form and therefore not absorbed. As a result, phosphorus need to be supplemented so that animals get the necessary P required. Studies have shown that addition of an enzyme, phytase, releases the phosphorus hence rendering it available. Consequently, rice bran be added at levels up to 35% if phytase is added. In a more recent study Radim and Alimon (2005) showed that increasing levels of rice bran have a negative effect on egg production in layer hens, and that supplementation of phytase improved production in birds fed 35% rice bran. Broiler chickens tolerate slightly lower rice bran than layer hens. Alimon et al (2001) showed that addition of phytase also increased the availability of zinc, iron and copper. This is because broiler chickens are bred to be fast growing and high FCR, and cannot tolerate high crude fibre in their diet. Ukil et al (1997) in his studies showed that 25% level is optimum for broiler chickens.

Rice straw

Malaysia produces about 1.5 million mt of rice and assuming the ratio of grain to straw is 1:0.9 and collectable straw at 50% then the estimated total straw production would be 825,000 mt and the same amount remaining as stubble. If intake of straw by a 350 kg cattle is assumed to be 6 kg per day then this amount of straw would be able to feed 376,00 animals for a year. However, it is common practice that straw is largely burned in the field instead of being collected and used as feed. Less than 10% is collected and used as feed or other purposes. Intake and digestibility of straw can be improved by physical and chemical treatments. Treatments with urea, ammonia or sodium hydroxide are easily carried out by small holder farmers and the improvement in intake is quite substantial. Yet, in Malaysia, little straw is used for animal feeds. The reasons being that straw is laborious to collect, bulky and poorly digested.

Large scale processing or commercial treatment of straw with alkali would incur additional costs may be not economically viable. However, several procedures have been developed to encourage smallholder farmers treat his own straw with minimal costs involved. Many factors contributed to the lack of response by farmers on the use of straw as animal feed. Poor transfer of technology, cost of treatment, poor response in terms of production by animals, presence of green forage throughout the year and possibly the lack of manpower to carry out the treatment are among the factors to be considered. The effect of various treatments on the digestibility and intake of straw is summarized in Table 3. In an early study, Alimon and Halimatun (1992) showed that rice straw diets with protein supplementation can support growth of 68 - 72 g per day in sheep. Treating rice straw with caustic soda (NaOH) and lime ($Ca(OH)_2$) improved intake by 15-20 percentage units. There are many ways of treating straw with NaOH. The traditional method of soaking in a 50% NaOH solution followed by rinsing is wasteful and eventually pollutes the environment. The method of injecting concentrated solution of NaOH during chopping of straw is more economical as the total NaOH will eventually be used up in the treatment of the straw during the standing period (usually 3-4 weeks) before feeding. Intakes of straw can also be improved by supplementing with molasses or a protein source. Fed alone, rice straw supports maintenance but may not be sufficient to meet the requirement for growth. Only when it is treated, e.g. NaOH treatment, the digestibility is increased thereby increasing digestible energy. However, long term feeding of NaOH treated straw may cause an overload of sodium in the animal. Animals need to drink a lot of water to help it rid the sodium in the body system. Under Malaysia context treatment with NaOH may incur additional costs and may not be economical.

Feeding in excess to encourage selectivity

Studies have shown that by exploiting the selective behaviour of small ruminants the intake of barley straw can be increased without added treatment or supplementation. Increase in intakes of up to 20% with increase in intake of digestible nutrients (Owen et al., 1987; Alimon et al., 1990). Selective animals tend to eat the leaves only leaving the stem which is of lower quality. By offering animals 100% more straw over that of the normal intakes encourages selectivity. However, this method has been dubbed as wasteful and that large quantities of straw are needed to allow selection to be practical. In another study, the residues after excess feeding is collected and treated with sodium hydroxide, and fed to goats. This procedure improves the total intake and digestibility of straw using less chemical (Alimon et al., 1990).

MAIZE STOVER

The growing of grain maize for animal feeds has never been an important agricultural activity in Malaysia due to several factors such as poor returns, lack of arable land and high costs of cultivation and high risk. However, there has been renewed interest in the growing of sweet corn for human consumption. In fact, areas under sweet corn is increasing though the Department of Agriculture cannot give an exact figure, the area under sweet corn is estimated to be more than 7000 ha. Sweet corn requires 60 - 70 days of growing period before the cobs are harvested. The cobs are usually picked just before it matures that is in the milky stage. At this stage the forage is still green and very palatable. It is common practice that the stover are cut and removed or burned. Three crops can be obtained in a year and therefore the period between harvesting and planting is rather short.

In areas where sweet corn is cultivated, large amounts of maize stover and maize cobs are produced. Studies by Alimon and Yacob (1992) showed that these stovers can be used as feed for ruminants. Large ruminants are able to feed on the stubble directly. Also, it is quite usual for farmers to harvest the sweet corn when the cobs are not fully ripe such that the leaves and stems are still green. Studies by Yacob et al (1994) showed that the sweet corn stovers contain between 7 - 9% crude protein and a digestibility of above 50 %. Sheep fed stover silage without any additives but supplemented with 100 and 200 g of concentrate were able to grow at 80 - 120 g per day. Further work is necessary in this aspect as different type of sweet corn gives different quality silages.

COCOA PODS

Cocoa is obtained from the seed of the cocoa fruit. The cocoa pods are priced open to remove the seeds and after the process of fermentation the seeds are processed to obtain the cocoa powder and cocoa butter. By-products from the cocoa industry include cocoa pods, which are usually discarded on- farm, and cocoa skins, obtained after processing of cocoa seeds. The cocoa skins are sometimes used as animal feed. Cocoa pods, like other fibrous by-products, contain about 27% crude fibre and 8.5% crude protein. It is estimated that about 0.5 million tonnes of cocoa pods are produced annually, yet less than 10% is used as animal feed. Much of dried cocoa pods are burnt or discarded. Although some work has been done to show that cocoa pods can be safely included to up to 30 percent in ruminant rations few farmers have taken up using cocoa pods as an ingredient in ration formulation. There were also suggestions that cocoa pods contain pesticide residues that could affect production of milk and growth of growing animals, but such claims have not been proven. It is known, however, like with many fruit cultivation, that in the cocoa plantation, pesticides are often used . To what extent pesticides residues still remain in the pods is not known. Of course, there are other problems associated with this material, for instance, it is highly fibrous, low in digestibility and palatability and high in tannins. In the wet form (fresh) it is known to contain toxin known as theobromine which can be destroyed when cocoa pods are dried.

PINEAPPLE WASTES

Pineapple waste is a good source of energy for ruminants. It is comparatively digestible but has a low protein content. With appropriate supplementation (i.e. protein source, vitamins and minerals) this feed can support growth of beef cattle of up to 1000 g /d live weight gain. Pineapple waste is high in moisture content (85 -87%) and need to be pressed to remove part of the water to encourage maximum intakes. However, studies have shown that the moisture content of pineapple waste did not affect intake. Pineapple waste, mixed with poultry litter, and fortified with minerals and vitamins is a suitable beef cattle ration.

SUGAR CANE

In Malaysia, sugar cane is not considered to be an important cash crop. However, it is widely grown for the production of sugar cane juice for local consumption. The cane is pressed between two rollers and the juice is sold in the chilled form by street vendors. The waste after juice extraction, which can be called bagasse, is usually discarded. Some sugar cane is also grown, on a large scale especially in the north of peninsular Malaysia where sugar extraction plant is available, for cane sugar extraction. Here, by-products of the sugar industry are available. The main by products are molasses and bagasse. Bagasse being of low digestibility and highly lignified is usually used as fuel within the factory. Sugar cane bagasse obtained after the extraction of sugar cane juice can be successfully ensiled and kept for long periods. This material can also be treated with urea to increase its digestibility and crude protein content (Alimon et al., 1994). Sugar cane tops are also available at the farm level. Studies overseas have shown that sugarcane tops are a valuable source of energy because it is high in sugar. It is not known if the sugar cane tops and the bagasse are at all used in Malaysia for feeding ruminants. The molasses are sold to feed millers for use in animal feeds.

Molasses

Molasses is a by product of the sugar refining process. It is dark brown in colour and thick liquid in texture, very much like honey, and consists of sugars such as sucrose. Traditionally, molasses is a readily digested and a good source of energy. Malaysia does not produce very much molasses, but whatever is produced is used in the feedmill industry as a feed ingredient to increase energy content and as a binder in the process of pelleting compounded feeds. In cattle fed CR such as sugar cane tops, supplementation with molasses improved weight gains in beef cattle, as molasses is also a by pass energy source and a useful additive to highly fibrous diets to encourage intake.

SAGO MEAL AND SAGO WASTES

Another source of energy for animals is sago meal and sago wastes. In Malaysia, the state of Sarawak has about 20,000 hectares substantial areas under naturally grown or cultivated sago (Metroxylon sagu, Rott.,). Sago belongs to a group of palms that accumulates starch in its trunk. It has been exploited as an energy source both for human and animal. Sago meal is made from the pith of the sago trunk and is a high energy feed because of the starch content. The pith is rasped, ground and dried to become sago meal. Sago waste is the byproduct obtained after starch is extracted from the sago pith and is usually discarded. Sago waste is a useful energy source for pigs and cattle. It is high moisture and bulky and transportation can be a problem. Its crude protein content is very low but is an excellent source of energy for ruminants and pigs and can safely be included at about 50% of the ration.

FOOD INDUSTRIES BY PRODUCTS

Poultry Wastes

In the processing of chicken meat the main waste are feathers, inedible offals such as legs, head, intestines and skins. This waste represent a problem to the industry as it can pollute the environment. Unprocessed feathers cannot be digested by non ruminant, but when hydrolysed by cooking at high temperature and under sufficient pressure it is highly digestible. Hydrolysed feather meal has a crude protein content of about 80%, high in cystine and an ME of 12 MJ/kg. However, hydrolysed feather meal is deficient in certain amino acids especially lysine. The use of feather meal is usually limited to 5-10% of the diet. Poultry byproduct is obtained after the wastes from the processing plant, which include feathers, offals, intestines and skins, are cooked under pressure dried and ground. This product is gaining importance in Malaysia as a number of large processing poultry plants are currently operating in Malaysia. This product is a valuable protein source as it contain about 60-65% crude protein, fat about 10% and ash 18%. The product also contain about 3.7% calcium and 2% phosphorus. The recommended inclusion in livestock rations is 10-15%.

LIVESTOCK WASTES

Poultry Manure, Broiler litter, Layer manure

The litter from broiler farms, which included wood shavings, waste feed, feathers and chicken excrement have been used as a nitrogen source in cattle feed. Usually the level of inclusion is within 10-15% of the diet. Analyses of broiler materials showed that the crude protein content ranges from 15-38% and crude fibre 11 - 50%. Litter from layer houses contain less crude fibre but high in calcium and phosphorus, as broken eggs contribute to their contents. In the US broiler litter has been used for more than 30 years without harmful effects on animals or humans who consumes the products. In Malaysia the use of broiler litter is not widespread as the consumers are quite reluctant to consume products from animals fed this material.

Blood Meal

Blood meal is obtained from the slaughterhouse. Blood is coagulated, dried and ground to produce a meal. It is extremely high in crude protein (80%) but the protein is lower in quality and digestibility than other animal protein. It is not very palatable to most livestock and for this reason it is included at lower than 5% in the diet.

NEW TECHNOLOGIES IN IMPROVING NUTRITIVE VALUE OF BY-PRODUCTS

Fermentation Technology

Fermentation technology is currently gaining importance in effort to improve the nutritive value of PKC. PKC is known to contain complex carbohydrates, mannans complexes, which are not easily digested in the non-ruminant stomach. In solid state fermentation techniques, scientists are able to improve the protein content by some 10 –15 percentage units and at the same time decrease crude fibre content using different microorganisms. However, the fermented products when tested for digestibility and palatability was not as expected. Intake by poultry was in fact reduced while the digestibility was significantly affected (Swe et al., 2004). They concluded that while *Aspergillus niger* is a common fungi used in solid state fermentation to improve the nutritive value of tapioca wastes, etc. it is not suitable for PKC. In their study, solid state fermentation of PKC using *Aspergillus niger* improved crude protein content by about 50%, and significantly decreased NDF content, but TME determination revealed there was no improvement in the energy content (Swe et al., 2004). It was thought that the increase in protein content was attributed to increase in mycelium mass, which was mainly non protein nitrogen. Delaying sporulation using ammonium sulphate did not affect the quality of the product obtained (Swe et al., 2004). Other microorganism often used in fermentation is *Trichoderma viride.*

Enzymes

Using a cocktail of enzymes, which include cellulase, mannanase, etc. to digest the cellulose and the fibre components in PKC has been shown to improve digestibility for poultry. The Improser Group of Companies have built a pilot plant in Pasir Gudang Johor, to treat and process PKC using this technology. It was claimed that the process improved the metabolisable energy and crude protein content and that the product can be used to replace partially corn in poultry diets.

CONCLUDING REMARKS

There are many other by-products and crop residues that I have not discussed in this paper, simply because these products are not available in Malaysia, or if available in small amounts. Also sometimes one byproduct may be used in one country but may not in another country. In Europe by-products like citrus and beet pulps are available, while in the Middle east olive pulp is available. It is utmost importance that we recognize what we have and develop our own feed resources to guarantee that we become less dependent on imported feedstuffs. It is also important that we recognize the limitations of certain feedstuffs in terms of nutritive value, palatability or possibly logistics in handling. Many visiting scientists from Europe or the America commented that Malaysia is so abundantly green and forage is available throughout the year and that Malaysia should not have any problems with feed supply. Of course, these visitors may not be aware that forages and green trees are not necessarily feed for animals. There are many challenges that face the animal nutritionist. Of late, problems of pesticides mycotoxins and dioxin appear to harass feed-millers and feed exporters. The demand for safe feed and food is priority in some countries. Animal welfare is gaining importance and the feeding of antibiotics and other growth promotants have been under scrutiny. The demand for halal meat and meat products, not only tracing back to whether animals are lawfully slaughtered according to the muslim rites, but going back to whether they are fed clean and halal feed which is the basis of safe, healthy and wholesome meat. Perhaps, the time has come that animals should be treated as well as humans should. Food for animals should be of similar quality as human food.

Before I end, there are a number of recommendations and suggestions that I would like us to consider:

- Agricultural engineers need to develop machines that can help farmers collect and process AIBP.
- Processing of OPF so that the midrib can be separated from leaf blades. In fact the leaf blades contain higher crude protein and energy and therefore can be treated as a leaf meal.
- Need more research on bulk handling and transportation of AIBP
- Waste from agricultural and food industries should be fully utilized so that wastage is minimized. Mechanisms by which waste can be trapped and separated for further processing.
- Use of cheaper chemicals to treat straw and other fibrous products
- The government should regulate the export of PKC so that local consumers have the priority.

- Concerted effort by plant breeders, together with animal scientists, in developing new hybrids of crops that are not only high yielding but also yield residues of high quality for feed.

- Livestock productionist and nutritionist should develop feeding strategies to combat irregular feed supply and variable quality.

Last but not least, we must remember that agricultural activity involving animals are not always very profitable, as it is a well known fact that agricultural enterprises have a small profit margin. The returns are low and slow and without government support this industry will not be able to survive. But we must keep this industry alive because food is important. The government should find ways and means of promoting the livestock industry for food security reasons.

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