WATER SPINACH (Ipomoea aquatica) AS A FEED RESOURCE FOR GROWING RABBITS

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SUMMARY

Rabbits are herbivores which efficiently convert forages to food for human beings. On the other hand, water spinach can be fed alone as the sole diet of rabbits as it appears to supply all the nutrient requirements including minerals, vitamins and water. In this case the feeding level should not be above 8% of the body weight (DM basis) to ensure that the rabbits consume the stems which have higher fiber content than the leaves. With this feeding system the growth rates ranged between 14 and 20 g/day with DM feed conversion of between 3.8 and 5.3.

Fibre plays an important role in the nutrition of the rabbit. There is a minimum requirement of dietary fiber in term of optimizing the digestive processes. Thus when the offer level was raised to 18% of body weight (DM basis) the rabbits preferentially selected the leaves and although digestibility and intake of crude protein were increased, the fiber intake was reduced and the live weight gain declined.

Water spinach is easy to grow on soil or in water and is highly responsive in growth to fertilizers. Even more, water spinach responds dramatically to fertilization with organic manure, especially the effluent from biodigesters. These advantages plus its high nutritive value for rabbits gives it a unique role in integrated farming systems for smallholder farmers.

Key words: *rabbits, water spinach, Ipomoea aquatica, feedstuff*

Short title: *Water spinach for rabbits*

ESPINACA ACUATICA (Ipomoea aquatica) COMO RECURSO ALIMENTARIO PARA CONEJOS EN CRECIMIENTO

RESUMEN

Los conejos son herbívoros que convierten eficientemente los forrajes en alimento para el ser humano. Por otra parte, la espinaca acuática puede ser dada sola en la dieta de los conejos puesto que parece que ella le suministra todos los nutrientes requeridos por el animal, incluidos los minerales, las vitaminas y el agua. En este caso, el nivel de consumo no debiera ser por encima del 8% del peso corporal (en base seca) para asegurar que los conejos consuman los tallos que tienen un contenido de fibra más alto que las hojas. Con este sistema de alimentación, el crecimiento puede estar en el rango de 14 a 20 g/día y la conversión alimentaria entre 3.8 y 5.3 kg MS consumida/kg de aumento.

La fibra desempeña un papel importante en la nutrición de los conejos. Hay un requerimiento mínimo de fibra en la dieta en términos de optimización de los procesos digestivos. Por lo tanto, cuando la oferta se eleva a 18% del peso corporal (en base seca), los conejos seleccionan preferentemente las hojas y aunque la digestibilidad y el consumo de proteína aumenta, el consumo de fibra se reduce y así también declina la ganancia diaria de peso.

La espinaca acuática crece fácilmente en el suelo o en agua y responde dramáticamente a la fertilización con desechos orgánicos, especialmente efluentes de biodigestores. Estas ventajas, más su alto valor nutritivo para los conejos, le confiere una posición única en sistemas integrados de producción para pequeños campesinos.

Palabras claves: *conejos, espinaca acuática, Ipomoea aquatica, alimento*

Título corto: *Espinaca acuática (Ipomoea aquatica) para conejos*

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INTRODUCTION

Rabbits are herbivores which efficiently convert forages to food. The whole point of sustainable systems of meat production is to convert plant proteins into animal protein of superior nutritive value for people, especially pregnant women and children (Waterlow 1998). According to Lebas et al (1997), rabbits in efficient production systems can turn 20 percent of the proteins they eat into edible meat. Comparable figures for other species were quoted as 22 to 23 percent for broiler chickens, 16 to 18 percent for pigs and 8 to 12 percent for beef. Rabbits can also utilize the available proteins in cellulose-rich plants, whereas it is not economical to feed these to chickens and turkeys, the only animals with higher energy and protein efficiency. The traditional grain and soybean meals fed to these domestic poultry put them in direct competition with humans for food. For countries with no cereal surpluses, rabbit meat production is thus especially interesting (Lebas et al 1997; Pok Samkol and Lukefahr 2008).

In the view of the worldwide demand for additional sources of food, the exploitation of plants of low economic importance would be a step towards better resource utilization (Telek and Martin 1983). This is in line with the strategy to achieve sustainable animal production systems by matching them with the locally available feed resources (Preston and Sansoucy 1987). Water spinach is used traditionally in Cambodia as a vegetable for consumption by people and animals. It has a short growth period and is resistant to common insect pests. However, there appears to be no information in the literature on its response to fertilizer especially fertilizer of organic origin as is produced by the anaerobic digestion of livestock manure (Kean Sophea and Preston 2001). It does not appear to contain antinutritional compounds and has been used successfully for growing pigs as the only source of supplementary protein in a diet based on broken rice (Ly 2002; Chhay Ty and Preston 2005). Prak Kea et al (2003) reported a linear increase in growth rates in pigs fed water spinach, palm oil and broken rice when up to 6% fish meal replaced equivalent amounts of water spinach, which they attributed to an improved amino acid balance, especially in terms of the sulphur-rich amino acids.

Recent research has explored the feasibility of using water spinach in combination with broken rice as a readily digestible feed for growing rabbits (Miech Phalla 2002, unpublished data; Hongthong Phimmasan et al 2004; Vo Thi Tuyet Nga 2004). However, most of these reports are of a preliminary nature.

RABBIT PRODUCTION IN THE WORLD

Lebas and Colin (1992) suggested that world production of rabbit meat is of the order of 1.5 million t. This would mean an annual consumption of roughly 280 g of rabbit meat per person; however, most inhabitants in many countries consume no rabbit meat whatsoever as compared with the 10 kg/year consumed by French farmers and 15 kg/year per head in Naples, Italy (Lebas and Colin 1992; Colin and Lebas 1994). Europe is indeed the centre of world rabbit production. The foremost world producers, far surpassing all other countries, are from Italy, the Commonwealth of Independent States countries (particularly Russia and Ukraine), France, China and Spain. Europe accounts for 75 percent of world production. China is the second place, specifically certain central Chinese provinces such as Sechuan. Production areas are also found in some regions of Africa, Central America and Southeast Asia, particularly Indonesia. Rabbits are not reared in most countries of the Near East. The annual consumption of rabbit meats is shown in table 1.

Tabla 1. Estimated annual rabbit meat consumption in selected countries, per caput (kg of carcass per person per year)

Country	Carcass weight	Country	Carcass weight
Japan	0.03	Thailand	0.31
Benin	0.04	Ghana	0.32
Congo	0.04	Bulgaria	0.39
China	0.07	Germany	0.44
Brazil	0.08	Nigeria	0.45
Hungary	0.10	Tunisia	0.48
South Africa	0.11	Malaysia	0.50
Argentina	0.12	Poland	0.50
Peru	0.13	Netherlands	0.63
United States	0.14	Romania	0.64
Mexico	0.18	Greece	0.70
Jamaica	0.20	CIS[1]	0.75
Canada	0.23	Slovenia	0.77
Colombia	0.24	Morocco	0.78
Syria	0.25	Czechia	1.72
Algeria	0.27	Portugal	1.94
Egypt	0.27	Spain	2.61
Indonesia	0.27	Belgium	2.61
United Kingdom	0.27	France	2.76
Vietnam	0.27	Cyprus	4.37
Philippines	0.29	Italy	5.71
Venezuela	0.30	Malta	8.89

[1] Former USSR
Source: Lebas et al (1986); Lebas and Colin (1992)

FEED PREFERENCES AND FEEDING BEHAVIOUR OF RABBITS

Rabbits are very selective in their feeding behaviour and in the wild will nibble and select specific plant parts. They generally select leaves rather than stems, young plant materials rather than old and green rather than dry materials, resulting in a diet that is higher in protein and digestible energy and lower in fibre than the available total plant material. They are much more sensitive to slight changes in the feed than other livestock. Sometimes they will refuse to accept a new diet and will starve rather than even taste the new feed for several days (McNitt et al 1996).

Lukefahr (1992) presented information on suitable feed sources and basic primary dietary requirements and concluded that feeds for rabbits could be obtained from a variety of sources. These included: wild, indigenous plant stands, cultivated forage plots, farm crop residues, farm surplus foods, agricultural by-products, kitchen wastes, and market sources. However, the wild plants may be poor in palatability and some forage may be only be seasonally available. He suggested cultivating forage plots on the farm with recommended species, managing the plots for the best yields, finally making the harvest and feeding the forage at the proper time. Ryan (1988) included sixteen feedstuffs that could be recommended to be grown without much care and regular watering such as: Desmanthus virgatus, Sesbania grandiflora, Euphorbia hirta, Cicca acida, Ocimum sanctum, Erythrina variegata, Cyperus rotumdus, Acalypha indica, Solanun nigrum, Raphanus sativus, Moringa concanensis, Solanum torvum, Kydia calycina, Leucas aspera, Manihot esculenta and Kirganelia reticulata. He recommended that two thirds of the ration must be given at night and a third stored for the next morning.

THE DIGESTION PROCESS

The feed taken by rabbits is first mashed up by the teeth and mixed with saliva, which contains enzymes to begin breaking down the food. When the food is swallowed it enters the stomach where it is mixed with stomach acid and digestive enzymes, which continue the digestion process (Tessmer and Smith 1998). The following description of the digestion process is given by Lebas et al (1997):

“Feed eaten by the rabbit quickly reaches the stomach. There it finds an acid environment. It remains in the stomach for three to six hours, undergoing little chemical change.

The contents of the stomach are gradually injected into the small intestine in short bursts, by strong stomach contractions. As the contents enter the small intestine they are diluted by the flow of bile, the first intestinal secretions and finally the pancreatic juice. After enzymatic action from these last two secretions the elements that can easily be broken down are freed and pass through the intestinal wall to be carried by the blood to the cells. The particles that are not broken down after a total stay of about one and a half hours in the small intestine enter the caecum. There they have to stay for a certain time, from two to 12 hours, while they are attacked by bacterial enzymes. Elements which can be broken down by this new attack (to produce mainly volatile fatty acids) are freed and in turn pass through the wall of the digestive tract and into the bloodstream. The contents of the caecum are then evacuated into the colon.

Approximately half consists of both large and small feed particles not already broken down, while the other half consists of bacteria that have developed in the caecum, fed on matter from the small intestine. So far, the functioning of the rabbit's digestive tract is virtually the same as that of other monogastric animals. Its uniqueness lies in the dual function of the proximal colon. If the caecum contents enter the colon in the early part of the morning they undergo few biochemical changes. The colon wall secretes mucus which gradually envelops the pellets formed by the wall contractions. These pellets gather in elongated clusters and are called soft or night pellets. If the caecal contents enter the colon at another time of day the reaction of the proximal colon is entirely different. Successive waves of contractions in alternating directions begin to act; the first to evacuate the contents normally and the second to push them back into the caecum. Under the varying pressure and rhythm of these contractions the contents are squeezed like a sponge. Most of the liquid part, containing soluble products and small particles of less than 0.1 mm, is forced back into the caecum.

The solid part, containing mainly large particles over 0.3 mm long, forms hard pellets which are then expelled. In fact, as a result of this dual action, the colon produces two types of excrement: hard and soft. The hard pellets are expelled, but the soft pellets are recovered by the rabbit directly upon being expelled from the anus. To do this the rabbit twists itself round, sucks in the soft faeces as they emerge from the anus, then swallows without chewing them. The rabbit can retrieve the soft pellets easily, even from a mesh floor. By the end of the morning there are large numbers of these pellets inside the stomach, where they may comprise three quarters of the total contents.

From then on the soft pellets follow the same digestive process as normal feed. Considering the fact that some parts of the intake may be recycled once, twice and even three or four times, and depending on the type of feed, the rabbit's digestive process lasts from 18 to 30 hours in all, averaging 20 hours. The soft pellets consist half of imperfectly broken down food residues and what is left of the gastric secretions and half of bacteria. The latter contain an appreciable amount of high-value proteins and water-soluble vitamins. The practice of coprophagy therefore has a certain nutritional value. The composition of the soft pellets and the quantity expelled daily are relatively independent of the type of feed ingested, since the bacteria remain constant. In particular, the amount of dry matter recycled daily through coprophagy is independent of the fibre content of the feed.

The higher the crude fiber contents of the feed and/or the coarser the particles, the sooner it passes through the digestive tract. On the other hand, this particular function requires roughage. If the feed contains few large particles and/or it is highly digestible, most of the caecal contents are pushed back to the caecum and lose elements which nourish the normal bacteria living in the caecum. This would appear to increase the risk of undesirable bacteria developing in this impoverished environment, some of which might be harmful. It is thus advisable to include a minimum of roughage in the feed, enabling the rabbit's digestive process to be completed fairly rapidly.

In theory, roughage is provided by the crude-fibre content of the feed, as this is normally rather hard to digest. However, certain fibre sources (beetroot pulp, fruit pulp in general) are highly digestible (digestibility of crude fibre varies from 60 to 80 percent)”.

UTILIZATION OF FIBRE

In general, the fibre fraction of feeds is poorly utilized by rabbits (table 2). If the rabbits digest fibre so poorly, how do they make efficient use of fibrous feeds? This apparent contradiction can be explained by recognizing that fibre makes up only 20 to 25% of forage materials. Thus, a foliage like alfalfa meal is 75 to 80% of non-fibre materials. The rabbit efficiently digests the non-fibre fraction, such as the protein and soluble carbohydrates, and defaecates the fibre fraction (McNitt et al 1996). Despite the favorable digestibility of the crude protein of leucaena leaf meal for rabbits (Raharjo et al 1986), graded additions of this legume to a control diet precipitated progressive depressions in growth such that, at the 400 g/kg inclusion, weight gain was less than 40% of control values (Tangendjaja et al 1990).

Table 2. Digestibility of fibre from alfalfa hay by various animals

Animal	Fibre digestibility,%
Cattle	44
Sheep	45
Goats	41
Horses	41
Pigs	22
Rabbits	14

Source: McNitt et al *(*1996)

According to Lebas et al (1997), the poor digestibility of the fibrous parts of raw materials such as alfalfa and straw makes them secondary to starch in covering energy needs. However, the fibrous components from tender, usually young plants are much more digestible. They can then provide 10 to 30 percent of energy requirements in favourable conditions. The fibrous parts have another function as providing bulk, which is generally evaluated on the basis of crude fibre content. In term of receiving enough bulk for growing rabbits, 13 to 14 percent crude fibre content seems to be satisfactory. The more digestible the fibrous parts the higher the total input needed to supply at least 10 percent indigestible crude fibre. Feeds with too low fibre content may cause diarrhea.

UTILIZATION OF COPROPHAGY BY RABBITS AND ITS CHEMICAL COMPOSITION

The major nutritional consequence of coprophagy in the rabbits is that this is a means to provide the requirements for B vitamins. All the members of the B complex group are synthesized by bacteria in the rabbit hindgut and made available to the rabbits after they consume the soft faeces. As a result, rabbits do not require B vitamins in their diets. Another consequence of coprophagy is that it provides a small amount of bacterial protein.

Rabbits excrete two types of faeces. The hard faeces, which are produced in the large intestine, are the faecal pellets commonly seen. The faeces that are consumed via coprophagy are the soft faeces, produced in the caecum (McNitt et al 1996). Lukefahr (1992) reported that the consumption of soft faeces of rabbits was a means of providing nutrients that could be recycled for digestion and absorption purposes. As a result, vitamin K and B vitamins are not required in the diets, since they are synthesized through coprophagy and fermentation in the caecum and hindgut.

Proto (1980) offered rabbits with ten different feed sources, which were either balanced concentrate feeds, or green and dry forages, and measured the nutrients in the hard and soft faeces (table 3). The major difference in composition was in the DM content (lower in soft faeces) and crude protein (much higher in the soft faeces).

Table 3. Composition of hard and soft faeces from ten different feed sources, % in dry matter basis except for DM which is in fresh basis

Components	Hard faeces	Soft faeces
Dry matter,%	48-46	18-37
As% in DM		
Minerals	3.1-14.4	6.4-10.8
Crude fiber	22-54	14-33
Ether extract	1.3-5.3	1.0-4.6
Nitrogen-fee extract	28-49	29-43
Crude protein	9-25	21-37

Source: Proto (1980)

PROTEIN AND AMINO ACID REQUIREMENTS FOR RABBITS

Rabbits digest the protein in the forages efficiently compared with other monogastric animals. Due to coprophagy, the rabbits have the ability to digest protein more than pigs, for example: pigs fed alfalfa will digest less than 50% while 75 to 80% is digested by rabbits, in spite of the fact that they do not digest the fibre fraction more efficiently than pigs do (McNitt et al 1996). Many researchers have studied the effect of crude protein levels in the diets on the performance traits of growing rabbits (Porsmouth 1977; McNitt et al 1996; Lei et al 2004).

The general conclusion was that low dietary crude protein levels reduced production performance and high dietary crude protein increased economic profit, weight gain, slaughter performance and nutrient digestibility (Lei et al 2004). Lei et al (2004) also reported that daily weight gain increased as crude protein level was raised from 14 to 20%, then decreased at the 22% crude protein level, with a similar trend for feed conversion. Daily weight gain and feed conversion were 19.4 g/day and 3.8 when crude protein in the diet was 19.5%, which were better than was achieved with 16.7 or 12.0% crude protein in the diet (Tang 1987). Wang (1999) showed that the daily weight gain was 29 g/day when the dietary crude protein was 16.5%, which was higher than for the 13.5, 15.0, 18.0, 19.5 and 21.0% crude protein groups. Feed conversion was 3.5 when the dietary crude protein was 18.0%, which was better than in the 13.5, 15.0, 16.5, 19.5 and 21.0% crude protein groups.

The recommended amounts of the essential amino acids in the diet of young and fattening rabbits are shown in table 4. These recommended amounts have been estimated simply on the basis of the composition of regular satisfactory diets. When these essential amino acids are supplied by a well balanced protein, then 15 to 16% crude protein in the diet DM should be enough for fattening rabbits.

Rabbits will always eat more of a balanced feed containing essential amino acids than the same feed without amino acids. Amino acid balance can easily be achieved with plant protein alone as is the case in almost all balanced feeds used in Europe. Proteins of animal origin can be used by rabbits but are absolutely unnecessary: all that counts is the amino acid intake, not the origin.

Table 4. Recommended chemical composition (%) of feeds (usually pelleted feeds containing cereal grain and alfalfa) for intensively reared rabbits of different categories

Components	Young rabbits	Mixed
Crude protein	16	17
Digestible protein	11.5	12.4
Amino acids		
Methionine-cystine	0.60	0.60
Lysine	0.70	0.70
Arginine	0.90	0.90
Threonine	0.55	0.60
Tryptophan	0.13	0.13
Histidine	0.35	0.40
Isoleucine	0.60	0.65
Phenyl alanine + tyrosine	1.20	1.25
Valine	0.70	0.80
Leucine	1.05	1.20

Source: Lebas (1989)

WATER SPINACH FOLIAGE AS A FEED SOURCE FOR RABBITS

The role of water spinach in integrated farming system

Two common types of water spinach are normally cultivated in Cambodia and other countries id South East Asia, for growing either on the soil or in the water. Water spinach grown on the soil has long, narrow leaves with pointed ends. The succulent foliage and stem tips are light green in colour. In order to obtain seeds, water spinach is allowed to develop the mature flowers, from which seed bearing pods are formed. Two main cultivar groups can be distinguished: variety Aquatica and variety replans. The first is an aquatic plant or paddy vegetable in Southern part of India and Southeast Asia, propagated by cuttings and growing in the wild or cultivated in the fish ponds and water courses. The second is an upland vegetable, cultivated on dry or marshy land and propagated by seeds or cuttings (Palada and Crossman 1999).

Water spinach grows well at high ambient temperatures and is commonly cultivated in Southeast Asia for humans and animals. It is an important feed source for pigs in Cambodia as well as in Vietnam, because it is easy to grow and is readily available. In Malaysia and Fiji, it was reported that water spinach is used to feed dairy cattle in combination with elephant grass (Pennisetum purpureum) (Göhl 1981).

Among aquatic weeds, water spinach has great potential for use as feed foliage and is effective in waste water treatment systems. Average annual fresh weight production of 90, 70 and 100 t/ha have been reported in Hong Kong, Fiji and the Netherlands, respectively, and the dry weight production during an eight months period exceeded 20 t/ha when grown in a culture solution (Jain et al 1987). Kean Sophea and Preston (2001) reported high yields of water spinach of over 20 t/ha in a 28 day period; the equivalent of 90 to 120 t/ha per year was recorded by Sath Sonetra (2002).

Biomass yield of water spinach after 28 days of cultivation was higher (2.85 t DM/ha) when fertilized with worm casts than with urea (2.49 t DM/ha), each applied at up to 60 kg N/ha (Tran Hoang Chat et al 2005).

Chemical composition of water spinach

Water spinach may be regarded as a potential source of feed protein concentrate. The edible portion can contain up to 29% crude protein on a DM basis, and may be as suitable a source of feed protein as alfalfa leaves (22% crude protein) (Thacker 1990). Moreover, water spinach has a lower fibre content than alfalfa leaves (Bruemmer and Roe 1979).

Tran Hoang Chat et al (2005) reported that water spinach foliage had a high potential as a supplement to concentrates for rabbits and supported higher live weight gain, milk yield and lower feed cost, compared with guinea grass.

According to Oomen and Grubben (1978) and Naren Tung et al (1994), water spinach is also a rich sources of minerals and vitamins, being especially rich in vitamins A (carotene), B1, B2 and C and in iron. The trace minerals content of fresh water spinach (mg/kg) were: Zn 5.03, Mn 22.2, Cu 1.37 and Fe 75.3 (NIAH 1995). The chemical composition of fresh whole plant water spinach is shown in table 5.

Table 5. Chemical composition of fresh water spinach foliage

Components, %	Water spinach
Water	91.6
Crude protein	1.90
Lipid	0.80
Cellulose	1.40
Non-protein N	3.20
Minerals	1.10
ME, MJ/kg	9.70
Amino acids	
Lysine	0.14
Methionine	0.07
Threonine	0.14
Tryptophan	0.04

Source: NIAH (1979); Naren Tung et al 1994)

According to Naren Toung et al (1994), a vitamin/mineral premix did not need to be included in diets containing water spinach as no deficiency symptoms of ducks were observed on this diet.

The ability of water spinach to supply minerals and vitamins is an important advantage in the rural areas where premixes are not usually available or are expensive. Based on the previous observation (Miech Phalla 2005, personal communication), water was not provided as the fresh water spinach plant contained almost 90% moisture so that the rabbits were able to satisfy their needs from the feed source (386 g/head/day of water for growing rabbits with air temperature 30^{o}C) according to Eberhart (1980). The important characteristics of water spinach foliage are shown in table 6.

Table 6. Characteristics of fresh water spinach foliage, % in DM except for dry matter which is on fresh basis

	Ratio	DM[1]	CP[2]	CF[3]	Source
Water spinach grown in water					
Leaves	-	12.9	31.9	-	Phimmasan
Stems	-	8.43	18.2	-	et al (2004)
Leaves	46.1	11.6	35.1	8.58	Pok Samkol
Stems	53.9	6.87	20.5	17.2	(2005)
Foliage	-	9.07	27.6	17.1	Prak Kea et al (2003)
Water spinach grown on soil					
Leaves	71.7	7.34	11.4	19.1	Pok Samkol
Stems	28.3	11.6	27.8	7.30	(2005)

[1] DM expresses dry matter
[2] CP expresses crude protein (Nx6.25)
[3] CF expresses crude fibre

Water spinach as a sole feed for rabbits

It has been shown (Pok Samkol 2005) that the digestibility of water spinach by rabbits was very high (80.5, 80.1, and 80.8% for DM, crude protein, and organic matter, respectively). Similar findings were reported by Honthong Phimmasan et al (2004). The digestibility coefficients in the experiment of Pok Samkol (2005) were higher than reported by Lei et al (2004) for the dietary crude protein in the level of 18% (60.8%, 72.1% and 66.8% for DM, crude protein and organic matter).

For a commercial pelleted feed, Ramchurn et al (2000a) reported 69.2% for DM and 74.0% for crude protein. Using a combination of Star grass with mash, the values were 68.8% for DM and 81.3% for crude protein (Ramchun et al (2000b). Bamikole and Ezenwa (1999) fed Verano stylo and reported values of 50.2% for DM and 61.4% for crude protein; Cunha et al (2004) offered alfalfa as source of fibre with digestibility coefficients of 61.4% for DM and 73.2% for crude protein, respectively.

The decrease in fibre digestibility, as the proportion of DM consumed as leaves increased (Pok Samkol 2005), indicates that the crude fibre in the leaves is less digestible than the crude fibre in the stems. This is the opposite of what occurs with most plant species where the cell wall component is less digestible in stems than in leaves (Van Soest 1994). The reason for this difference could lie in the architecture of the water spinach plant. The stems (or stolons) of the water spinach rest on the soil (or in the water) and thus do not have to support the leaves. In contrast, in most plants the stems are upright and physically support the leaves (Rangnekar 1991).

Fibre plays a vital role in the nutrition of the rabbit. According to Lebas et al (1997), there is a minimum requirement for roughage in order to optimize the digestive processes, and the more digestible the fibre the higher is the requirement in order to satisfy the need for 10% of indigestible fibre in the diet. However, the problem with water spinach would not appear to be one of too high digestibility of the fibre, but rather too low concentration of fibre in the total plant. This hypothesis is supported by recent findings from an experiment in which two other sources of high-fibre feeds (grass and rice straw) were offered to rabbits in addition to the water spinach (Pok Samkol unpublished data). DM intake was increased by 50% when the rabbits had access to all three feed sources as compared with water spinach as the sole diet.

Table 7. Performance of rabbits fed a range of diets in tropical countries

Diets	DG, g/day[1]	FC, kg/kg	Source
Water spinach	14.0	5.3	Pok Samkol (2005)
Water spinach	20	3.8	
Banana/sweet potato mash	10	7.0	Nguyen Quang et al (2000)
Concentrate/grass	17.5	-	Dinh et al (1991)
Green grass	2.7	35	Roy et al (2002)
Whole cassava plant	11.2	6.0	Akinfala et al (2003)
Pelleted commercial diet	14.8	7.8	Ramchurn et al (2000b)
African star grass	7.7	10.9	Ramchurn et al (2000a)
Cereal grain/CSM/ SBM	10.9	4.5	Mbaya et al (2005)
Maize/SBM + sugar cane leaves	19.5	-	Bien-Aimé and Denaud (1989)
Sorghum offal	13.0	3.7	Uko et al (1999)
Concentrate/water spinach	31.4	3.87	Tran Hoang et al (2005)

[1] DG and FC expresses daily gain and feed conversion rate, respectively

Growth performance and feed conversion of rabbits fed only water spinach were in the range 14 to 20 g/day and 3.83 to 5.3, respectively (Pok Samkol 2005), which is superior to findings reported from several tropical countries for a range of other feed resources (table 7).

The high nutritional potential of water spinach for rabbits is confirmed by the very high growth rate (31.4 g/day) that was recorded when it was given ad libitum as a combination with concentrates (Tran et al 2005).

BROKEN RICE AS FEED SUPPLEMENT FOR RABBITS

According to Göhl (1985) broken rice is separated after the polishing stage. There is seldom any surplus of broken rice available for feeding to livestock as much as mixed back with the whole grain rice and sold as low grade rice. In some countries it is used for the production of arak or serves as the raw material for rice flour. The percentage of rice by-products is dependent on the milling rate, the type of rice, and the machine used for processing the grain. The whole rice contains 20% hulls, 10% bran, 3% polishing, 1-17% broken rice and 50-60% polished rice. Broken rice is palatable and rich in energy.

It has been used for all classes of live stock. But it is of special value in rations for growing chickens because of its high energy value and low fiber content (Göhl 1985). However, it has limited availability for use as feedstuff for pigs (Farrell and Hutton (no date, cited by Pok Samkol 2005)). The chemical composition of a good sample of broken rice is similar to that of polished rice but feed quality material may contain some contaminations. Chemical composition will vary with rice cultivar, growing conditions and season (Farrell and Hutton no date, cited by Pok Samkol 2005). This may be observed in data from table 8.

Table 8. Chemical composition of broken rice, % in dry matter basis (except for DM which is on air-dry basis)

DM[1]	CP	Ash	OM	EE	Source
87.6	7.10	0.50	99.5	0.90	Creswell (1987)
88.6	6.37	1.19	98.8	-	Pok Samkol
89.5	6.88	1.20	98.8	-	(2005)

[1] DM, CP, OM and EE express dry matter, crude protein (Nx6.25), organic matter and ether extract respectively

Broken rice has a high digestible energy (DE) content of 14.5 MJ/kg (Farrell and Warren 1982) which compares with 15.5 MJ/kg DM for polished rice. Broken rice is relatively low in protein but the essential amino acid balance is good. The amino acid composition of broken rice from Malaysia and Thailand is shown in table 9. These analyses suggest that broken rice is superior to maize. The amino acid composition of seven samples of broken rice from Malaysia and nine samples from Thailand, expressed in percent as fed.

Table 9. Amino acid content of broken rice from Malaysia and Thailand (in percent)

Amino acid	Malaysia	Thailand
Dry matter	87.2	87.5
Arginine	0.65	0.55
Histidine	0.19	0.16
Isoleucine	0.35	0.30
Leucine	0.66	0.57
Lysine	0.31	0.26
Methionine	0.23	0.18
Phenyl alanine	0.44	0.38
Threonine	0.28	0.24
Tyrosine	0.32	0.25
Valine	0.74	0.40

[1] Source: Creswell (1988)

Inclusion of broken rice in the diet based on water spinach of growing rabbits did not improve the growth rate or the feed conversion (Hongthong Phimmasan et al 2004; POK Samkol 2005). The fact that the volatile fatty acid concentration in the faeces was increased when broken rice was fed suggests that it was not completely digested in the small intestine and the remainder was digested by fermentative activity in the caecum. The lack of a growth response to supplementation with broken rice would appear to be the primary limiting factor is low fibre in water spinach. However it would also reduce protein supply particularly if it is mainly fermented in the caecum because the level of crude fibre in the water spinach was already borderline (or even too low), such that the addition of the low-fibre broken rice would thus reduce the crude fibre of the overall diet even more.

CONCLUSIONS

Water spinach can be fed alone as the sole diet of rabbits as it appears to supply all the nutrient requirements including minerals, vitamins and water. In this case the feeding level should not be above 8% of the body weight (DM basis) to ensure that the rabbits consume the stems which have higher fibre content than the leaves. With this feeding system the growth rates ranged between 14 and 20 g/day with DM feed conversion of between 3.8 and 5.3.

From the point of view of the water spinach composition, it is well known that fibre plays an important role in the nutrition of the rabbit. There is a minimum requirement of dietary fibre in term of optimizing the digestive processes. Thus when the offer level was raised to 18% of body weight (DM basis) the rabbits preferentially selected the leaves and although digestibility and intake of crude protein were increased, the fibre intake was reduced and the live weight gain declined.

On the other hand, it must bear in mind that water spinach is easy to grow on soil or in water and is highly responsive in growth to fertilizers responds dramatically to fertilization with organic manure, especially the effluent from biodigesters. These advantages plus its high nutritive value for rabbits gives it a unique role in integrated farming systems for smallholder farmers.

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