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A REVIEW: ECONOMIC FEED INGREDIENTS FOR PIGS

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ABSTRACT

On the basis of available literatures a review had been made on available economic feed ingredients for pig rearing like cassava, sweet potato, bananas and plantains, other tuber crops like yam, taro or cocoyam or Colocasia, pine apple, jack fruit, guava, byproducts of pomegranate peels and seeds, pomace of orange and apple, sunflower press cake, kewi, waste of brewery and winery industry and feeding alcohol distilling residues etc. The chemical composition and feeding trial on the basis ADG(Average daily gain), DE(Digestible energy), DM(Dry matter), GE(Gross energy), crude protein(CP), crude fiber(CF), EE(Ether extract), N(nitrogen),NFE(Nitrogen free extract), OM(Osteomalacia) discussed to ascertain their efficacy to use as pig feed ingredients with Special reference to sates of North-East Zone of India like Assam, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura and Sikkim are potential source of all the said crops as people of these states have good choice of pork eating. It was observed that though some works on the mentioned feed ingredients periodically since decades back with conclusion. But no proper practice of using of alternative source of energy, proteins, minerals, vitamins with antioxidant property might due to lack of awareness amongst the small pig holders to reduce the feed cost. Unutilized or spare land should be used for cultivation of tuber crops like tapioca or cassava with sweet potato, colocasia of high yielding varieties, with least managemental cost for economic feed ingredients of pig feed. The forest department of each state may help the farmers through silviculture by inclusion of said crops.

Key words: Economic, Feed ingredients, North-East Zone, Pig, Silvicultue.

Broadly breeds and nutrition are two major factors which may have combined effect on production in terms of investment and return. So, there is great need to search for economic source of energy and protein in place of major cost bearing feed ingredients for reduction of feed cost for rearing of pigs. The tribal and non-tribal people of low income groups of North-East zone of India have first choice of keeping pigs as small house-holding and as well as the subsidiary economic source. However, it is observed that the feed accounts for 60-80% of the total cost of production. Therefore judicial economic feeding is very essential to have maximum benefit. Farmers frequently use crop residues, green fodder and kitchen leftovers to reduce feeding costs and in many cases supplement these with commercial or home-mixed concentrates. Pig production is not only a major protein source for human consumption but the manure from it is also important in supplying organic fertilizer. While a good amount agricultural by-product such as beer by-product, pineapple pulps are also feed source for pig.

The energy that is stored in roots, tubers, bananas and plantains does not differ significantly from that in cereals. Maize, high in energy due to its low fibre content and the high digestibility of its starch, is frequently used as the standard with which to compare other sources of energy for animals. However, roots, tubers, bananas and plantains are also rich sources of carbohydrate energy and, as such, constitute one of the basic components of the human diet in the tropics and subtropics (Alhassan and Odoi 1982, Annonymous, 2017). Because they can tolerate a wide range of climatic conditions and infertile or marginal lands, their production is relatively stable which means that they are particularly well suited to sustainable farming systems.

Many parts of India suffer from recurrent food shortage. Moreover, feed ingredients are of the costlier for pig farming. Such types of feed ingredients are, therefore, frequently unavailable feeding animals and so, alternative of energy sources must be searched.

So, veterinarian expert has to develop awareness amongst pig farmers for minimizing feed costs if profits are to be maximized. However, the feed must contain the nutrients in the right quantities and correct method of feeding must be used.

The main objective of this chapter is to show that the digestible energy content of these alternative feedstuffs approximates that of cereals, therefore, they might offer considerable potential to furnish a considerable large share of the nutrients currently provided by more conventional energy sources for pigs.

CASSAVA

Cassava (*Manihot esculenta* Crantz) is one of the major sources of carbohydrates for humans in many developing countries including India. There has been increasing interest in the feeding value of cassava for pigs while the average yield is 10 t/ha (FAO, 1991) recent data from Brazil have shown that it is possible to obtain 68 t/ha by using improved varieties, reasonably fertile soil and good management (Chandra, 1986).

Chemical composition

Cassava roots contain 30 to 40% dry matter, more than most roots and tubers which is depends on factors such as variety, soil type, moisture, climatic conditions and the age of the root at harvest. Starch is the predominant components of the cassava tuber , approximately 90%, with starch while the yield of cassava leaves, depending on the variety and soil fertility, can vary from 2 to 8 tons of dry matter/ha/year (Oke 1978).

Although the crude protein content of cassava root is 2 to 4% in dry matter, the true protein content is 50% of the nitrogen in the roots in the form of non-protein-nitrogen. Furthermore, the available true protein is deficient in the sulphur-containing amino acids (Table 2). The roots contain significant amounts of vitamins, particularly vitamin C, thiamine, riboflavin and niacin. The root contains lesser crude protein, crude fibre, amino acids than that of leaves (Table 1 and 2).

Table 1. Chemical composition of cassava roots and leaves (% DM).

Composition	Roots		Leaves
	Domínguez (1985)	Ravindran *et al.* (1982)	Ravindran *et al.* (1982)
Crude protein	3.5	2.9	20.2
Ether extract	0.8	1.4	6.2
Crude fibre	4.2	5.0	29.0
Ash	4.1	2.3	7.8
Nitrogen free extract	87.4	88.4	36.8

Table 2. Amino acid composition of cassava roots and leaves (g/16g N).

Amino acid	Roots	Leaves	
Threonine	2.08	3.52	Ravindran *et al.* (1982)
Valine	2.78	5.30	
Methionine	0.70	1.29	
Isoleucine	2.08	4.06	
Leucine	3.80	7.43	
Phenylalanine	2.80	4.81	
Lysine	0.35	4.81	
Total	59.11	84.90	

Cassava leaves have a relatively high crude fibre and crude protein content (17 - 34%) crude protein in dry matter of cassava leaf (Ravindran *et al.* 1983). The amino acid pattern shows that cassava leaf protein is deficient in methionine but rich in lysine (Table 2). Since harvesting the leaves every two months does not affect root yield, and does increase leaf yield (Luteladio and Egumah 1981), an interesting alternative might be to treat the leaves and roots as two distinct crops: the roots for carbohydrates and the foliage for protein, vitamins and minerals.

Cyanogenic glycosides, linamarin and lotaustralin are the limiting factors present in cassava roots and leaves are to be considered seriously. These glycosides, upon contact with the endogenous enzyme, linamerase, produce hydrocyanic acid. The reaction is initiated when the roots are crushed or the cellular structure is otherwise damaged. Presently, interest is centered on using varieties naturally low in glycosides and in the development of processing methods which reduce the danger of hydrocyanic acid toxicity.

Processing method of cassava root and leaves

Some of the processing methods reported to reduce or eliminate the toxicity of cassava roots (Maner 1973 and Tewe 1992) Boiling destroys the enzyme linamerase, removes the free cyanide and also the glycosides. Chopping or crushing, followed by sun drying, removes both the glycosides and the hydrocyanic acid; while drying with hot air removes the free hydrocyanic acid and destroys the enzyme, but leaves the glycosides largely intact. Ensiling can cause the destruction of the intact glycosides, thereby reducing the content of cyanide. In some varieties, the leaves contain even more cyanogenic glycosides than the roots; however, Rajaguru *et al.* (1979) pointed out that sun-drying can eliminate most of the cyanide in the leaves.

Digestibility

Several studies have emphasized the high digestibility of cassava root diets for pigs, and their comparison to cereals (Table 5). Sonaiya and Omole (1977**)** reported that digestibility was not effected by using up to 15% cassava in the diet, however, earlier studies had shown that with piglets (Aumaitre 1969, Arambawela *et al.* 1975) and older pigs (Maust *et al.* 1972) the digestibility of cassava-based diets was superior to that of cereals. Likewise, no effect on the nutrient uptake was reported by Chicco *et al.* (1972) when cassava completely substituted maize. Tillon and Serres (1973), in support of this same observation, found that the digestibility of cassava root was not significantly modified by grinding, heating or drying and that the digestible energy of cassava root was comparable to that of maize and other cereals.

The low values were attributed to the high crude fibre content and the presence of tannins in the leaves. Although cassava leaves are not a common source of energy (Allen (1984).

Fresh cassava roots

Raw cassava can supply the major source of energy for growing/finishing pigs (Table 4). Feeding *ad libitum* on a ration of chopped raw cassava roots and a protein supplement, growing/finishing pigs gained weight less rapidly but as efficiently as those of feeding a maize-soya bean meal ration. The consumption of chopped fresh cassava roots by growing/finishing pigs varies according to the protein content of the supplement. The voluntary daily intake of cassava roots was reported to increase throughout the growing/finishing period when the amount of protein supplement increased (Maner *et al.* 1977). Trials have shown that fresh cassava, of low cyanide content and properly supplemented with a source of protein, minerals and vitamins, can be used as a major source of energy throughout the entire swine life cycle. However, if they are fed bitter roots, performance will suffer, consumption will decrease and they will exhibit a lower average daily gain, and in some cases even lose of weight gain (Gómez *et al.* 1976) so in the case of wild varieties.

Cassava root silage

Sun drying should be practiced in presence clear weather with sufficient sun light in the humid tropics zone otherwise it will result in a low quality product with severe *Aspergillus* mould and related aflatoxin contamination. Artificial drying of cassava roots can be made to diminish hydrocyanic acid (Gómez and Valdivieso 1988).

Tab 4. Performance of growing/finishing pigs fed fresh cassava roots.

% DM in diet	Liveweight (kg)	ADG (g)	DM feed conversion	Source
0	18-99	840	3.43	Maner *et al.* (1977)
68	"	790	2.80	
0	21-86	750	2.81	Maner *et al.* (1977)
60	"	650	3.02	
0	20-54	680	2.84	Buitrago *et al.* (1978)
51	"	630	2.76	

Buitrago *et al.* (1978) compared cassava root silage to fresh chopped cassava roots for growing/finishing pigs and found that the average daily gain and dry matter feed efficiency were similar. There is limited information in respect to the use of chopped cassava root silage for sows, its use for growing/finishing pigs indicates that performance is comparable to that of chopped fresh cassava roots (Table 5).

Table 5. Performance of growing/finishing pigs fed * different forms of cassava: fresh, chopped, chopped root silage and root and foliage silage

Treatment	% in diet	Live weight(Kg)	ADG(g)	DM conversion	
Maize control diet	0	20-54	680	2.84	Buitrago *et al.* (1978), * plus a protein supplement
Fresh chopped cassava	51	"	630	2.76	
Chopped cassava root silage	50	"	650	2.98	
Fresh chopped cassava	61	18-98	750	3.43	
Chopped cassava root silage	60	"	770	3.25	
Root and foliage silage	53	"	640	3.52	

Cassava root meal

A comprehensive studies on cassava meal for pigs had been conducted by researchers from the Colombian Agricultural Institute and the International Center for Tropical Agriculture (CIAT). Cassava meal was prepared by chopping the whole root and drying it in a forced air oven at 82C. When the dry cassava meal substituted maize in a 16% crude protein concentrate ration there was a slight decrease in average daily gain as the level of cassava meal increased, however, feed intake was similar for all groups indicating that palatability was not a problem (Table 6). Addition of 10% molasses increased consumption and improved average daily gain in all groups. A second experiment evaluated various protein supplements with high levels of cassava root meal where performance was again satisfactory. Presence of the vitamins with trace minerals improved performances.

Aumaitre (1969) compared iso-nitrogenous diets containing 50% cassava root meal to diets with the same amount of barley, oats, wheat or maize. Here it was observed that the average daily gain of weaning pigs of 5-10 weeks of age was higher on the cassava diet and live weight gains were reported to be 416, 386, 380, 360 and 354 g/day, respectively. Feed per unit of gain was similar for all groups. The University of Hawaii (Gómez 1992) had shown that piglets from weanined between 20-25 kg, fed diets containing 20 to 25% cassava meal, performed similarly or slightly better than those fed a maize-soya bean meal ration.

Table 6. Cassava root meal for growing/finishing pigs (% DM)

% DM in diet	Liveweight (kg)	ADG (g)	DM feed conversion	Source
0	19-105	770	3.47	Maner *et al.* (1977)
69	"	710	3.49	
0	16-95	710	3.30	CIA T (1978)
68	"	650	3.40	
0	21-96	720	2.67	Lougnon (1979)
50	"	680	2.93	

When cassava root meal was fed at levels of 22, 44 and 66% (Shimada 1970) from 30 to 90 kg, performance was lowered, only, with the group fed the highest level. Feeding with cassava root meal enriched with o.2% methionine improved feed consumption and growth, and increased urinary thiocyanate excretion (Cresswell 1978)

Researchers at CIAT have studied the effects of cassava/soya bean meal or maize/soya bean meal diets on swine reproduction. A consistent trend to produce smaller litters (8.4 *vs*. 10.0) when sows were fed on cassava meal (Maner 1973, Gómez *et al.* 1976, Gómez 1977) was attributed to a deficit of methionine. However, Gómez *et al.* (1984) showed that supplementation with 0.3% methionine did not improve reproductive performance and suggested that incorrect handling of the meal might have explained the difference (Table 7). Interestingly, piglet survival rate at 56 days on the methionine treatment was similar to that of maize.

Table 7. Cassava root meal* for pregnant-lactating gilts

Performance parameters	Maize	Cassava meal	Cassava meal plus 0.3% methionine	Gómez *et al.* (1984), * soya bean meal as protein supplement
Gilts farrowed	14	10	10	
Average number piglets born	8.5	9.1	9.4	
Average birth weight, kg	1.09	1.06	1.07	
Piglets weaned/litter at 56 days	7.1	8.2	8.0	
Average piglet weaning weight, kg	16.9	16.2	16.5	

Wyllie and Lekule (1980) con ducted two experiments were carried out with Large White x Landrace pigs. In the first cassava root meal was substituted for maize at rates of 0, 18, 36 and 54% of the diet. The maize protein was replaced by a soya bean-sesame meal mixture in a 1: 2 ratio. The diets were fed from 41 kg to 90 kg live weight according to a feeding scale giving levels of energy and protein intake below those for maximum growth. There were no significant differences between treatments. The diet containing 36% cassava was the most economic in terms of the food cost of carcass gain. In the second experiment equal weights of cassava root meal and final cane molasses were substituted for one another at levels of 0, 17, 34, 51 and 68% of the diet. They were fed on a severely restricted scale from 38 to 80 kg liveweight. Daily gain and food conversion efficiency increased linearly as the cassava content of the diet increased.

Lekule *et al.* (2007) had conducted three experiments were carried out to evaluate the nutritive value of fresh unpeeled cassava tubers, peeled, soaked cassava tubers, cassava root meal and cassava chips as energy sources for growing finishing pigs. Performance of pigs was comparable to pigs fed other energy sources (or commercial cereal based diet). Pig growth rate ranged from 478 to 660 g/pig /day. Digestibility and feed efficiency of cassava-based diets were high, although young pigs (below 20 kg) tended to develop gastro-intestinal disturbances and parakeratosis when fed fresh cassava. The carcass quality was slightly affected. Carcasses from pigs fed on cassava diets were leaner and heavier than those on other rations. The studies concluded that varieties of sweet cassava could be fed fresh to pigs either peeled or unpeeled or in form of cassava chips. Further, fresh cassava can be soaked in water for one day whereas cassava chips can be dried for 8 to 10 hours prior to feeding to reduce HCN levels. Cassava can constitute the only energy source in diets of pigs provided that such diets are well balanced for protein, minerals and vitamins. Thus use of cassava in feeds of pig will provide a sustainable source of energy.

Bonia (2008) reported that there was no significant variation in live body weight gain at any stage of growth on different feeding rations with cassava powder (Table 8 and 9) whereas the average values were varied significantly between week($P<0.01$). The body weight gained was positively correlated with the quantity of feed consume by the pig though the trend of growth pattern in all individuals were almost similar females grew a bit faster than that of females with no effect of pull values on this three feeding trials. In due course of time all females of experimental groups farrowed normally with no piglet mortality at birth time and all the litters thrived well in subsequent stages of growth period.

Cassava leaves

Growth performance was lowered as the proportion of fresh cassava leaves was increased in the ration of growing/finishing pigs (Mahendranathan 1971). This adverse effect was evidently due to the high level of hydrocyanic acid present in the fresh leaves, which affected the palatability.

Ravindran (1990) substituted 10, 20 and 30% cassava leaf meal in a maize/soya bean meal diet for growing pigs and found that the average daily gains and feed efficiency decreased linearly with increasing levels of leaf meal. The performance of pigs fed a diet containing 10% cassava leaf meal was improved by the addition of methionine and additional energy supplementation. This same author emphasized that the relatively high crude protein level and lysine content of cassava leaves might justify the development of processing methods that would make this feed resource more competitive for swine production.

Hence, unutilized or spare land should be used for cultivation of tapioca or cassava of high yielding varieties with least management cost and high yielding to be used as feed ingredient of pig feed.

SWEET POTATO

The productive potential of the sweet potato (*Ipomoea batatas* (L.) Lam.) varies from 24 to 36 t/ha of fresh roots (Morales 1980) and from 4.3 to 6.0 tons of dry matter/ha of foliage. It is also possible to obtain up to three harvests, yearly (Ruiz *et al*. 1980). Although, the main nutritional importance of sweet potato is in the starch, it is also a source of important vitamins, such as vitamin A, ascorbic acid, thiamine, riboflavin and niacin. Recently, it has been shown that the fresh vines can provide up to 27% of the dry matter and 40% of the total dietary protein for growing/finishing pigs.

Table 8. Composition (%) of the experimental diets

<table>
<tr><td rowspan="2">Feed ingredients</td><td colspan="3">Treatments</td><td rowspan="10">Bonia, 2007-08
*Chemical contains:
Vitamin A-50, 00,00 IU; Vitamin D3-10,00,000; Vitamin-2.00; Vtamin R-750IU,; Vitamin K-1g; Calcium pantothetite-2.50g; Nicotinmide-10g; Vitamin B_{12}-6mg, Chloride-150g; Clcium-750g; Manganese-27.5g; Iodine-1g; Iron-7.50g; Zinc-15; Copper-20g and Cobalt-0.45g</td></tr>
<tr><td>Diet I</td><td>Diet II</td><td>Diet III</td></tr>
<tr><td>Cassava powder</td><td>-</td><td>10</td><td>30</td></tr>
<tr><td>Maize</td><td>50</td><td>40</td><td>20</td></tr>
<tr><td>Rice polish</td><td>32</td><td>30</td><td>20</td></tr>
<tr><td>Mastared oil cake</td><td>10</td><td>12</td><td>15</td></tr>
<tr><td>Fish meal</td><td>6</td><td>6</td><td>6</td></tr>
<tr><td>Mineral mixture</td><td>1.5</td><td>1.5</td><td>1.5</td></tr>
<tr><td>Common salt</td><td>o.5</td><td>0.5</td><td>0.5</td></tr>
<tr><td>Nuvomin Fort*</td><td>250g</td><td>250g</td><td>250g</td></tr>
</table>

Table 9. Chemical composition(%) on dry matter basis (Calculated value)

Crude protein	15.20	15.32	14.57	
Crude fibre	2.64	3.66	5.74	Bonia (2008)
Ethar extract	10.13	10.13	8.69	
Ash	5.42	6.56	7.17	
Phosphorous	0.55	0.54	0.53	
Calcium	0.20	0.28	0.39	

Chemical composition

The chemical composition of sweet potato roots and vines is shown in Table 10. The roots contain low amounts of crude protein, fat and fibre; carbohydrates make up between 80 to 90% of the dry matter in the roots. The uncooked starch is very resistant to hydrolysis by the enzyme amylase, however, when cooked, the hydrolizable starch fraction increases from 4% to 55% (Cerning-Beroard and Le Dividich 1976).

Table 11 shows the nutritional quality and deficiencies of sweet potato roots and vines in total sulphur-containing amino acids and lysine in terms of an ideal protein for pigs (Fuller and Chamberlain 1982). It is to be stated that the typsin inhibitors in raw sweet potato roots decrease protein digestibility, but they can be destroyed by cooking (Martínez *et al.*, 1991).

Table 10. Chemical composition of sweet potato roots and vines (% DM)

Composition	Roots	Vines	
	Domínguez (1990)	Godoy and Elliot (1981)	Domínguez (1990)
Dry matter	29.2	15.0	14.2
Crude protein	6.4	18.2	18.5
Ash	5.3	17.7	12.5
Acid detergent fibre	5.5	22.3	23.5
Neutral detergent fibre	6.9	26.2	-
Lignin	0.7	5.7	-
Ether extract	0.6	-	-
Gross energy MJ/kg DM	17.1	-	14.4

Table 11. Amino acid content of sweet potato roots and vines (g/100 g protein).

Composition	Roots Ideal * protein		Vines	
	* Fuller and Chamberlain (1982)	Purcell *et al.* (1972)	Li (1982)	Walter *et al.* (1978)
Isoleucine	3.8	4.2-10.1	3.9-5.1	4.9
Leucine	7.0	7.8-9.2	6.2-7.9	9.6
Total sulphur	3.5	2.8-3.8	3.0-3.9	2.8
Phenylalanine + tyrosine	6.7	11.9-13.6	6.2-10.1	10.6
Threonine	4.2	5.5-6.3	5.1-6.1	5.3
Trytophan	1.0	0.8-1.2	-	-
Valine	4.9	6.8-8.3	4.9-8.2	6.3
Lysine	7.0	4.2-7.2	4.3-4.9	6.2
Chemical score: total sulphur	100	80-109	85-110	80
Lysine	100	60-103	61-70	88

Digestible nutrients

Sweet potato roots, raw or cooked, and peeled or non-peeled, have been evaluated in digestibility trials. Peeling significantly increases crude protein digestibility but has no effect on digestible or metabolizable energy, or on the total digestibility of nutrients. Although cooking increases the digestibility of nutrients, it does not affect the utilization of energy (Table 12). Wu (1980) found that the net energy of the sweet potato, 8.5 MJ/kg dry matter, was only 79% that of maize. Canope *et al.* (1977) reported that cooking improved the digestibility of all nutrients, especially nitrogen. Rose and White (1980) fed raw sweet potato roots to pigs and observed a low intake with a high digestible energy value, 15.8 MJ/kg dry matter.

Domínguez (1992) found that the inclusion, in dry matter, of 10% of fresh sweet potato vine to a diet of cooked sweet potatoes and soya bean meal lowered the digestibility of all nutrients. An increase in fibre was assumed to be the cause. However, the same author stated that the digestible energy value was acceptable, and even higher, compared to the value of 4.1 MJ/kg dry matter reported by Takahashi *et al.* (1968) for this foliage. Although in this diet the retention of nitrogen was low, it increased when 10% foliage was added, from 14.1 to 16.4 g/day, which suggests that sweet potato foliage is an acceptable protein source for pigs when included at moderate levels in the diet.

Table 12. Digestibility of sweet potato root diets (%).

Items	DM	OM	N	GE	DE (MJ/kgDM)	Source
Raw	90.4	92.1	27.6	89.3	14.1	Canope *et al.* (1977)
Cooked	93.5	94.5	52.8	93.0	14.5	
Raw	95.3	96.1	49.8	94.2	15.8	Rose and White (1980)
Cooked	85.5	-	76.0	89.2	14.7	Domínguez (1992)
Chips	-	91.8	52.3	89.3	15.3	Noblet *et al.* (1990)

Watt (1973) summarized the results of feeding sweet potato roots to pigs and concluded that the use of cooked, as compared to raw sweet potatoes, increased the average daily gain and that 500 g/day of a protein supplement supported optimal growth. Corring and Rettagliati (1969) also found that in rations for growing/finishing pigs cooked sweet potatoes were superior to that of raw form. The data in the following table show, that as raw sweet potatoes progressively replaced maize, the daily feed intake and average daily gain decreased, however, there were no significant changes in feed conversion (Table 13).

Table 13. Raw sweet potato roots (% DM) as an energy source for growing pigs (32-90 kg)

Maize/raw sweet potatoes *	88.2/0.0	46.8/42.4	22.4/69.5	8.5/84.3	Marrero (1975), * with a protein supplement
DM feed intake, kg/d	2.29	2.05	1.91	1.92	
ADG, g	740	650	580	570	
DM feed conversion	3.16	3.23	3.31	3.37	

Sweet potatoes can also be chopped, sun-dried, and used as an energy source for pigs. The data in Table 16 shows that the performance of pigs fed dried sweet potato chips, although inferior to pigs fed on maize, offers an additional and interesting option for feeding pigs in the tropics (Table 14).

Table 14. Dried sweet potato chips as an alternative energy source for finishing pigs

Sweet potato chips, DM	ADG (g)	DM feed conversion	Source
0	650	3.36	Tai and Lei (1970)
54-88	560	3.81	
0	840	2.92	Cornelio *et al.* (1988)
46	720	3.38	
0	640	3.79	Manfredini *et al.* (1990)
40	600	4.01	

Table 15 showing the performance of pigs fed a basal diet of cooked sweet potato, with or without the addition of fresh sweet potato foliage, to replace 25 and 50% of the soya bean meal in the basal diet. A maize/soya bean meal diet was used as the control. The results suggested that providing an adequate protein supplement, the cooked sweet potato may totally replace maize for finishing pigs. The use of the fresh vines, at both levels, decreased total dry matter intake. This was probably due to their low dry matter content, 12 to 15 percent. With the lower level of substitution, which implied the use of fresh vines at a level of 13.6% of total dietary dry matter, the feed conversion was similar to that obtained with the sweet potato/soya bean meal basal diet. The higher level of fresh vines, 27% of dietary dry matter, resulted in a poorer gain and increased feed conversion. In an earlier experiment, when Kohn *et al.* (1976) substituted sweet potato vines for part of maize/soya bean meal ration for pigs weighing 26-90 kg, it was also reported that the average daily gain decreased and the feed conversion increased.

The complete substitution of maize by cooked sweet potatoes for weaned piglets of 7 to 15 kg decreased the average daily gain from 329 to 284g and increased the dry matter feed conversion from 1.95 to 2.48 (Mora *et al.* 1990). When the fresh vines were used to replace 10% of total dry matter, Mora *et al.* (1991) found that performance of 6 to 12 kg weaners tended to improve, both from the point of view of average daily gain (186 *vs.* 202 g/day) and feed conversion (2.80 *vs.* 2.50).

Similarly, unutilized or spare land should be used for cultivation of sweet potato along with tapioca or cassava of high yielding varieties with least management cost and high yielding to be used as feed ingredient of pig feed.

Table 15. Use of sweet potato roots and vines for growing/finishing * pigs.

Constituent:	% DM				
Ground maize	83.8	-	-	-	Domínguez *et al.* 1991 * (30-90 kg)
Soya bean meal	16.2	18.4	13.8	9.2	
Cooked sweet potato	-	81.6	72.6	63.8	
Fresh sweet potato vines	-	-	13.6	27.0	
Initial liveweight, kg	29.2	28.6	29.2	29.2	
Final liveweight, kg	90.4	90.4	84.4	80.2	
DM feed intake, kg/d	2.30	2.71	2.46	2.43	
ADG, g	770	770	690	640	
DM feed conversion	3.01	3.51	3.55	3.81	

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BANANAS AND PLANTAINS

Although bananas (*Musa cavendishii*) and plantains (*Musa paradisiaca*) are mainly used as human food, a considerable amount of reject fruit could be fed to livestock, particularly to pigs. The vegetative part of the plant, the pseudo-stems and leaves, contains more than 60% of the dry matter of the whole plant (Table 16) and has been used experimentally as meal for pigs in concentrate rations (Garcia *et al.* 1991a,b).

Green bananas contain 20 to 22% of dry matter, mainly in the form of starch (Table 17). When bananas ripen, the starch changes into simple sugars, sucrose, glucose and fructose. Compared to the ripe pulp which contains only 0.5% lignin some 60% of the crude fibre in the whole green banana is lignin, and this affects its digestibility (Van Loesecke 1950). The inorganic fraction is poor in calcium and phosphorus but rich in potassium. Both green and ripe bananas have a low crude protein content and are particularly deficient in lysine and in the sulphur-containing amino acids. Additionally, green bananas contain tannins which cause the unripe banana to taste bitter and which can affect palatability, and therefore, voluntary consumption is reduced.

The digestibility of raw or cooked, peeled or non-peeled, green or ripe and fresh or dried bananas for pigs is presented in Table 20. The high level of free active tannins in fresh green bananas and their residual presence in fresh ripe bananas is reflected in their negative protein digestibility. The ripe meal form produced the poorest results with regard to nutrient digestibility. This was no doubt due to the elevated temperature employed during processing which destroyed many of the nutrients.

Table 16. Average yield of different parts of banana plants

Parts of the plant	Fresh		Dry matter		
	kg	%	kg	%	Foulkes *et al.* (1978)
Pseudo-stem	27.0	60.5	4.2	54.5	
Leaves	6.4	14.3	0.5	6.0	
Fruit	11.2	25.2	3.0	39.0	
Total	44.6	100.0	7.7	100.0	

Table 17. The chemical composition of bananas and plantains (%DM)

Components	DM	CP	CF	EE	Ash	NFE	
Banana pseudo-stems *	5.1	2.4	20.5	2.3	14.3	60.5	FAO (1993), ** Garcia *et al.* (1991a)
Banana pseudo-stems **	6.3	4.9	25.1	-	17.7	-	
Banana leaf meal *	94.1	9.9	24.0	11.8	8.8	45.5	
Fresh banana leaves **	19.5	11.4	28.3	-	10.9	-	
Plantain pseudo-stems *	-	2.8	13.8	1.2	15.6	66.6	
Plantain leaves *	-	9.5	23.1	5.6	13.3	48.5	
Green bananas *	20.9	4.8	3.3	1.9	4.8	85.2	
Ripe bananas *	31.0	5.4	2.2	0.9	3.3	88.2	

Table 20. The digestibility of different forms of ripe and green bananas for pigs

Type of banana	% digestibility					
	DM	OM	N	GE	DE (MJ /kg DM)	
Green bananas	76.9	-	-	-	13.39	Clavijo and Maner (1973)
Ripe bananas	84.3	-	102.0*	-	13.05	
Ripe banana meal	83.6	-	-42.7	-	7.13	
Green banana meal	83.6	-	26.6	-	13.42	
Green bananas	83.5	84.2	3.4	79.5	13.31	Le Dividich and Canope (1975)
Cooked green bananas	87.9	89.1	26.4	85.5	14.39	
Peeled green bananas	88.6	89.1	26.4	85.5	14.39	
Ripe bananas	89.5	90.1	38.4	85.5	13.92	
* Negative Protein Digestibility refers to the affect of this dietary component on total digestibility due mostly to						

Using bananas and plantains

Bananas can be fed to pigs either fresh, or in the form of a dry meal (Clavijo and Maner 1974, Le Dividich *et al.* 1976a, Le Dividich *et al.* 1976b) and India total production of this fruit is sarisfactory(Babatunde 1988).

Table21 . Performance of growing finishing pigs (1) fed ripe, green or cooked green bananas (2)

Parameters	Treatments				
	Control maize supplement	30% protein supplement3			Babatunde, 1988
		Plus ripe bananas	Plus green bananas	Plus cooked green bananas	
Avg. Daily Gain(kg)	0.68a	0.566	0.46c	0.50c	
Avg. Daily Feed(kg)					
Banana (kg)	-	8.85a	4.25c	6.20b	
Supplement (kg)	-	0.71a	1.04c	0.88b	

Ripe bananas are very palatable and their degree of ripeness affects growth performance of pig. If fed non-peeled ripe bananas *ad libitum*, the pig will first eat the pulp leaving part of the peel; however, fed on a restricted basis, both the pulp and peel are eaten. If fed high levels of green bananas, palatability there by affect voluntary intake and a lower consumption will affect the growth performance. Consumption of both bananas and plantains can be improved, however, be sliced the green banana followed by sun dried for pig feeding.

Although cooking green bananas improves consumption, growth performance but not equal to that of ripe bananas. Table 22 shows that when growing/finishing pigs were fed relatively low amounts of ripe or green bananas, approximately one-third of total dietary dry matter, with a restricted amount of protein supplement, they had similar average daily gains and feed conversions.

Table 22. Performance of growing/finishing pigs fed bananas in different forms (30-90 kg)

% DM in diet	Form	ADG (g)	DM feed conversion	
0	cereal (control)	680	3.41	Clavijo and Maner (1974)
45	fresh green	460	4.16	
59	cooked	500	4.26	
71	green	560	4.44	Clavijo and Maner (1974)
34	ripe	450	3.55	
36	ripe	460	3.55	
59	green	510	4.29	Solis *et al.* (1985)
66	ripe	570	4.63	

Calles *et al.* (1970) studied the performance of growing/finishing pigs fed free-choice ripe bananas with a restricted amount of either a 30 or 40% protein supplement. Growth performance, which significantly improved (660 *vs*. 770 g) when the 30% supplement was used, was assumed to be the effect of the additional intake of energy. It was suggested that the significant increase in the daily consumption of bananas during the first two to three weeks of the experimental period might have been associated, not only with the adaptation to a new feed, but also to the development of a larger stomach capacity.

Table 23 shows the performance of growing/finishing pigs fed on different levels of green banana meal. When fed at increasingly higher levels, Celleri *et al.* (1971) found a reduction in average daily gain and a deterioration in feed conversion. Similar studies by Zamora *et al.* (1985) confirmed that pigs fed green banana meal at levels higher than 20-25% had lower performance.

Table 23. Performance of pigs fed different levels of green banana meal (30-90 kg)

% DM in diet	ADG (g)	DM feeed conversion	Celleri *et al.* (1971)
0	670	3.66	
25	650	3.88	
50	630	4.04	
75	610	4.19	
0	620	4.09	Zamora *et al.* (1985)
20	620	4.12	
40	580	4.40	

If fresh ripe bananas used as a basic feed for the pregnant sow the litter size and average piglet birth weight after farrowing did not differ from the control group fed cereals. Again in fact, one group of pregnant sows fed fresh, ripe bananas showed an improved liveweight gain as compared to a similar group fed on cereals- upon farrowing there were no observed differences in the piglets. On the contrary, for the lactating sow, fresh, ripe bananas do not meet energy requirements, and feeding *ad libitum* may cause diarrhea which can affect performance (Clavijo and Maner 1971).

Green banana meal can supply 50% of the ration for lactating sows with no significant difference in litter size at weaning but with a loss of sow body weight due to less digestible energy. This could be important because a loss of sow body weight can affect future reproductive performance. When used at the same level in the diet of 5-week old weaned piglets, the green meal controlled diarrhoea and produced a growth performance comparable to that obtained with the same level of cassava flour (Le Dividich and Canope 1974).

Finally, banana leaf meal has been used to replace up to 15% of total dietary dry matter for growing pigs (Garcia *et al.*, 1991b) with satisfactory performance both from the point of average daily gain and feed conversion (Table 24).

From the nutritional point of view cooking, drying and milling do not have any advantage over whole; chopped; green or ripe fruit and so should be avoided wherever possible.

OTHER TUBER CROPS

Yam (*Dioscorea* spp.) is a tropical or sub-tropical root crop that grows extensively inthroughout the world and to a lesser extent in other tropical areas. Although there are many types of yam, the most economically important are the white yam, (*D. rotundata*), the yellow yam (*D. cayenensis*) and the water yam (*D. alata*). The nutritional composition of yam (Table 24) varies among species and cultivars. The major carbohydrate component is amilopectin and only a small proportion of the total carbohydrate fraction consists of mono and disaccharides. Although the percentage of tryptophan in yam is rather high (1.0%) while lysine is deficient and the other sulfur-containing amino acids.

Table 24. Use of banana leaf meal for growing pigs (14-28 kg)

% DM in diet	ADG (g)	DM feed conversion	
0	506	2.63	García *et al.* (1991b)
5	496	3.00	
10	505	2.91	
15	483	2.99	

Taro or cocoyam (*Colocasia esculenta* Schott), which originated in India and South East Asia, is presently cultivated in many tropical and subtropical countries. The starch grains of the corms are very small which makes taro highly digestible. The level of crude protein, although slightly higher than that in yam, cassava or sweet potato, contains low amounts of the amino acids like histidine, lysine, isoleucine, tryptophan and methionine.

Karimuribo et al. (2011) observed in Tanzania that the main basal ration fed to pigs as reported by farmers was maize bran (100%), green leafy materials (12.2%) and vegetable residues (4.9%). Supplementary feeds provided to pigs were mainly sunflower seed cake

(38.9%), vegetable residues (19.4%) and minerals (13.9%). The main production constraints identified by farmers included unavailability of animal feeds, inadequate animal health and inadequate extension service and diseases. Similar is the case in India. Despite availability of reliable market for pigs in the study area, the average number of pigs kept per farm was very small indicating existence of opportunity for increased pig production which could be sustainable in the area.

Table 25. Chemical composition of other tuber crops (% DM)

Composition	Dioscorea sp		Colocasia esculenta		
	Tubers	Leaves	Tubers	Leaves	
Dry matter	34.2	24.1	26.2	8.2	FAO (1993)
Crude protein	8.1	12.0	8.7	25.0	
Crude fibre	2.6	25.3	1.7	12.1	
Ash	5.2	7.9	4.0	12.4	
Ether extract	0.8	2.3	0.4	10.7	
Nitrogen free extract	83.3	52.5	85.2	39.8	

The Colocasia/taro leaf contains 25% crude protein in dry matter, rich in calcium, phosphorus, iron, vitamin C, thiamine, riboflavin and niacin. Although, some results of feeding trials using these tuber crops are presented (Table 26) normally excess of both yam and taro can be used as pig feed.

Table 26. Feeding trial of yam and taro

Tuber	Live weight (kg)	ADG (g)	DM feed conversion	
Cooked yam	20-56	580	3.25	Esnaola (1986)
Raw yam	20-43	510	3.40	CIAT (1978)
Cooked yam	20-43	760	2.53	
Cooked taro	30-59	590	3.20	Anónimo (1986)

Nguyen Ba Mui and Dang Thai Hai(2009) found that The pigs fed the pineapple pulp based diet produced (Table 26 and 27) less urine than in the pigs fed the rice bran and tapioca based diets (p<0.001). In the other two diets, tapioca was exchanged with the same amount (200 g/kg diet) of rice bran or pineapple pulp. Thus, the diets were similar, except for the contents of NSP-rich by-products and pineapple pulps. The diet based on pineapple pulp had the highest NSP content (18.92%), followed by the diets based on rice bran (12.88%) and the tapioca (6.95%). They also concluded that inclusion of sun dried guava pomace up to 30 per cent in diets of crossbred pigs had not significantly affected the growth performance and the carcass characteristics (Rao *et al*. 2004).

All parts of North- East zone like Assam, Arunachal Pradesh, Nagaland, Manipur, Sikkim and Tripura, presently producing good quantity of almost all horticultural products like jack fruits, orange, mango, guava, watermelon, kiwi, strawberry, wild apple wile Mizoram too dealing with Kiwi with integration of other fruits. Many industries with these fruits with these fruits are running and proposed to be established in this zone.

Table 27: Amount, pH and composition of faeces and urine from pigs fed different diets

Component	Tapioca (n=4)	Rice Bran (n=4)	Pineapple Pulp (n=4)	P1
Amount (g/day):				
Urine	4247a	3783a	3028b	***
Faeces	422a	622b	879c	***
Total N (g/kg):				
Urine	4.28a	4.11a	3.56b	**
Faeces	10.24a	9.73a	8.23b	**
pH:				
Urine	7.62	7.51	7.45	NS
Faeces	7.95a	7.73a	7.18b	**
Faecal CF (g/kg)	66.8a	72.8b	76.6b	**
Urine urea (mmol/l)	136.7a	17.5b	102.3b	***
Tot. urinary urea (mmol/day)	580.5a	444.5b	309.8c	***

Table 28: Composition of slurry at d 1 and d 30 and N loss from slurry during storage

Components	Tapioca(n=4)	Rice bran(n=4)	Pineapple (n=4)	P
Day 1				
Amount1, kg	22.34	21.02	19.53	NS
DM, g/kg	77.72a.	84.7a	96.8b	**
Total N, g/kg	5.37	5.51	5.62	NS
pH	794a	7.82a	7.21b	**
Day 30				
Amount1, kg				
DM, g/kg	15.19	14.65	13.86	NS
Total N, g/kg	106.31a	120.15b	138.63c	***
pH	6.62a	7.18b	7.41b	**
N loss (%)2	7.85a	7.79a	7.12b	***
	16.20a	9.21b	6.32c	***

The waste management is one of the major parts of food industries. The large volume of the low cost by-product gives economical advantage of its potentially valuable components and environmental benefits. Therefore, the recovery of by-products to health beneficial product and economic benefit to labour, stakeholder and country. The food industries categorized as 1) Fruit and Vegetable Industry 2) Grain Processing Industry 3) Brewery and Winery Industry 4) Marine Industry 5) Meat Industry 6) Dairy Industry.

Fruit and vegetable industry are the potential source of antioxidants and byproducts showed a high amount in glucose, citric and linoleic acids, tocopherols, and isorhamnetin-O-(di-deoxyhexosyl-hexoside. By-products as functional food ingredients, namely for antioxidant-enriched formulations, instead of being discarded.

Pomegranate peels and seeds, a by-product of pomegranate juice and concentrate industries, present a wide range of the pharmaceutical and nutraceutical properties (Kaderides *et al.* 2015). Orange pomace was mainly rich in fibres with applications suited to products requiring improved water/oil holding and binding properties for example a high water hydration capacity (4.40 ml/g). It had a valuable nutritional composition: high dietary fibre content (40.47%), low fat content (2.14%) and a high mineral content. Apple pomace showed high visco-elastic properties that could improve structures within products (O'Shea *et l.* 2012). Apple peels are considered as important by-product of apple industry and crore of tonnes of these peels are wasted every year due to inadequate or under processing

(Rabetafikaa *et al.* 2014). De-oiled sunflower press cake is a promising wellspring of nourishment protein as an alternative to soy and egg protein being devoid of toxic substances and low in antinutrients (Dietmar *et al.* 2014).

Brewery and winery industry

The brewing process promotes the generation of three intrinsic wastes, the spent grain, the hot trub and the residual yeast. BSG as the main by-product of brewing industry, representing approximately 85% of total by-products generated, is rich in cellulose and non-cellulosic polysaccharides. Beer is the fifth most consumed beverage in the world apart from tea, carbonates, milk and coffee. Spent grains are the by-products of mashing process; which is one of the beginning operations in distillery so as to solubilize the malt and cereal grains to ensure adequate extraction of the wort (water with extracted matter). The amount of brewers' spent grain (BSG) generated could be about 85% of the total by-products and raw material for extraction of compounds such as sugars, proteins, acids and antioxidants (Aliyu and Bala 2011). The use of waste of rice beer as pig feed in North-East Zone also drawining special attension(Sekar and Mariappan 2007).

Feeding Alcohol Distilling Residues

Local alcohol can be made from millet, rice, maize, sweet potato, bananas, and similar starch rich crops. Most popular for pig feeding is distillery wastes from millet and rice. It should be mixed with other feeds such as rice bran and broken rice/maize. Distillers' residues can be fed to fattening pigs, but not to pregnant or lactating sows. Yet, these animals require a high quality of feed and therefore distillery waste needs to be replaced by other high quality feed such as balanced diets. The following mixing ratio is commonly used in combination with distillery waste: Rice bran/Wheat bran (2 kg), broken rice (1 kg), and Distillers' residues (5-10 kg) and other locally available agricultural by-products.

Theory of feeding pigs (Annonymous 2017)

Pigs require 5 categories of nutrients obtained from feed stuffs.

i. Protein: for growth and body repair. The sources of protein include, feedstuffs of animal origin i.e fish, blood meal, poultry, both fish, animal and bird processing wastes.

Feedstuffs of plant origin include, soybean, beans, cottonseed cake and sun flower cake.

ii. Energy: For maintenance of normal body functions. The source of energy have a lot of carbohydrates (Starch and Sugars) or fat; These include cereal origins from maize, sorghum, millet, wheat.

Cereal processing products: Maize bran, wheat bran, rice bran. roots and tubers- cassava, sweet potato, yams, fruits like banana, Jack fruit, pineapple, guava etc. Animal fat is also a good source of energy.

iii. Vitamins for maintenance of normal health.

iv. Minerals: Most essential minerals for pigs are calcium, phosphorus and iron.

Calcium and phosphorus can be fed to pigs by including bone meal in the ration Iron is very important especially in piglets and can be given to pigs by allowing them access to clean red soil otherwise iron sulphate can be given to the pig as an oral formulation or as injection.

Daily Feed Requirements

Dry/pregnant Sows and Gilts

Dry sows and gilts require 2.5kg a day of sow and weaner meal. Give an extra 1kg/day one week before serving gilts and sows and one week after service. Give lactating sows 2.5 kg a day of sow and weaner meal for maintenance and 0.25 kg a day extra for each piglet being suckled.

Boars: Give boars 2.0 kg a day. If the boar is regularly used increase this to 2.5 kg.

Piglets: Give creep pellets 0.5 - 1.0 kg a day from day 7 up to weaning time (21 days) per piglet. The feed should be mixed with sow and weaner meal the last one week before weaning.

Feeding of Growing and Finishing pigs:

Pigs weaned at 3 - 5 weeks of 11 - 13 kg body weight should continue being fed on the starter diet until they reach 18 kg live weight. Pigs weaned at 7 weeks or older may be switched gradually to sow and weaner diet.

For growing or finishing pigs all ration changes should be made gradually. If this is not possible the feeding level of the new diet should be low until the pigs become accustomed to it. Where post-weaning scours are a major problem, restricted feeding during the first week after weaning may reduce the incidents of scours.

For treatment in case of an outbreak of scouring, medication through drinking water is preferable since sick pigs go off feed.

So, popularization of these feed ingredients is to be done much by state government, Krishi Vigyan Kendra(KVK) of Indian Council of Agricultural Research(ICAR) and NGOs for economic upliftment of poor farmers through piggery rearing. Moreover, The forest department of each state NE-Zone may help the farmers through silviculture.

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