The African Oil Palm in Integrated Farming Systems in Colombia: New Developments

Alvaro Ocampo Duran
University of the Llanos, PO Box 2621 Villavicencio, Colombia

Abstract
Recent work supports and extends the idea of using the African oil palm as a strategic resource within integrated tropical production systems.

The use of high-energy multi-nutritional blocks containing palm oil for beef cattle has been evaluated. Results show a significant increase in animal production especially in grazing systems based on the natural savannahs.

Pig production work has continued with the aim of refining the use of crude palm oil in the diet and increasing the use of protein rich forages like the leaves of *Manihot esculenta*, *Trichanthera gigantea*or *Azolla filliculoides* as replacements for soyabean meal. Also, a feeding and management system for grazing pigs has been designed with satisfactory results. This system, based on an integral approach, aims to improve the soil conditions of land which is destined for crop production.

The utilization of crude palm oil in the diet of broilers kept in a semi-confined system has resulted in similar performance to that of a confined system based on cereals, as well as permitting the inclusion of significant levels of protein-rich forages.

High-energy blocks have also been used with good results in African hair sheep production.

These systems offer new alternatives for small and medium-sized farmers to increase profitability, make better use of local resources, reduce dependence on external inputs and exploit the biodiversity of the natural ecosystem.

KEY WORDS: African oil palm, livestock, integration, *Elaeis guineensis*

Tropical Beef Production

The nutritive value of grasses is a major limitation to beef production in the tropics (Escobar, 1991). They are low in energy (especially in non-structural carbohydrates and lipids), protein and minerals. They are high in fibre which limits intake. The presence of secondary compounds in forages, particularly legumes, has very variable effects on the animal. The quality of forages themselves is very variable, both locally and seasonally, as a result of agro-ecological factors such as climate, soil, nutrient availability, topography, etc. These factors determine to a large part the productivity of tropical beef production, which is generally low when no action is taken to correct these limitations. This does not mean that the production potential is low. On the contrary, by understanding the limitations, it has been possible to design different strategies to significantly improve animal performance, including the provision of non-protein nitrogen, mineral supplementation, the use of pasture legumes and particularly legume trees, and health management.

Recently, Huertas (1996) conducted an analysis of feed efficiency in Colombian cattle production (Table 1), showing evidence of the same low levels of productivity as measured by the feed conversion ratio in extensive or semi-intensive systems based on grass pastures.

In terms of efficiency, there has not been any improvement from the practice of replacing natural pastures with introduced species, known as 'improved pastures'. But on the contrary, the introduction of legumes has succeeded, giving an important improvement in efficiency.

The cultivation of African Palm has the potential to offer various production alternatives, different products and by-products that can be utilized in the energy supplementation of cattle, improving efficiency and productivity.

Energy Strategy Using Multinutritional Blocks

The advantages of the use of multi-nutritional blocks, in diets based on crop by-products or pastures of typical low quality, are well known in terms of providing adequate non-protein nitrogen in the rumen, improving both function and efficiency, which is reflected in higher voluntary intake by the animal and better digestibility of fibre.

Table 1. Feed efficiency of cattle in Colombia

Ecosystem	Live weight kg	Ratio kg forage/1 per kg live weight gain	
		Grass	Grass +legume
Natural conditions	120	10:1	
Eastern Llanos	200	22:1	
	300	25:1	
Valle del Sinu	250-280	20:1	15:1
	300-350	22:1	18:1
Magdalena Medio	250-280	20:1	-
	300-350	22:1	-
Ladera Antioquena	230-260	22:1	18:1
	300-460	24:1	18:1
Piedemonte Llanero	220-260	22:1	18:1
	300-450	25:1	18:1

1/calculated on the basis of dry forage
Source: Adapted from Huertas (1996).

Work is in progress with blocks not just to supply nitrogen but as a way of offering additional energy using fat from palm oil and solubilized fatty acids.

The block being used contains 10% urea, 10% rice polishings, 40% molasses, 15% quick lime, 10% rice husks, 5% mineral salt and 10% crude palm oil or solubilized fatty acids. The content of crude palm oil can be raised to 15%, reducing the amount of rice husks to 5%.

In recent work, Ocampo *et al.* (1996) have supplemented cull cows with multi-nutritional blocks using two levels of crude palm oil, 10 and 15%, following the formula described above. The 30 cows with an average weight of 290 kg were on short pasture of Brachiaria decumbens, at an average stocking rate of 1 animal/hectare and three treatments: two with blocks and one control. The results are summarized in the following table.

Table 2. Average performance of female cattle following treatments (90 days experiment).

Variable	Control Block	Block 10% oil	Block 15% oil
Initial LW kg	300.6	288.6	290.5
Final LW kg	349.5	345.7	353.3
LWG g/day	544	634.4	697.7
Block intake g/d	0	111.1	123.3
Additional LWG from block g/day		90.4	153.7
Cost of block consumed USD		0.023	0.027
Value of extra LWG in USD		0.106	0.117

The animals that received blocks gave the best results, in both economic and biological terms. It is very important to emphasize the low intake of blocks, the response to which was significant to the animals, resulting mainly from the additional supply of energy.

Note how the difference between 0.023 USD and 0.027 USD daily represented an additional gain in production of meat that ranged from 0.106 USD to 0.117 USD, making it very worthwhile. It is not usual to encounter gains at pasture of 543 g/day, as shown in the control group, which was an indication of the good condition of the pasture.

Nevertheless, the response to the effect of blocks was good. This shows that the use of energy blocks works not only in the dry season but that it is worth using throughout the whole year, improving the return per unit area of the smallholding or farm.

Very interesting results were obtained in the analysis of rumen degradability of the block, being approximately 50% at 6 hours for both blocks, 65% at 24 hours and 76% at 72 hours. The nitrogen content of the blocks had a degradability of 40% at 6 hours, 63% at 24 hours and 79% at 72 hours. Similar results were found with the NDF content. It can be concluded that supplementation with energy blocks improved overall animal performance, demonstrating that the effect of additional fat as a source of energy is viable.

Further work carried out in the Puerto Gaitan area, Departamento del Meta, Colombia evaluated the response to energy blocks by fattening cattle, with 45 steers per treatment lasting 67 days, and an initial average live weight of 250 kg. There were 4 treatments: one on Brachiaria decumbens without block, another on natural savannah without block and two on natural savannah (*Axonopus purpussi*) with blocks containing 10% crude palm oil or solubilized fatty acids (SFA).

The results which are reported in the above table show once more the validity of the energy strategy using multi-nutritional blocks.

It leads to an interesting discussion of the production achieved on natural savannah of Axonopus purpussi compared to that on Brachiaria decumbens. The daily LWG is practically the same and the only difference is in carrying capacity which resulted in greater annual meat production per hectare from the improved pastures'. However, the latter depends on converting the local ecosystem by removing the natural pasture, adapted over many years and with a high capacity for persistence. In addition, the costs of establishment and maintenance of the introduced pasture implies a very great cost in order to achieve the levels of production reported.

The increase in production achieved on the natural savannah is highly significant, with minimal inputs and a high rate of return. To increase production to 90 kg/ha/year solely by introducing the block system is a very interesting finding and raises the issue of the politics of substitution of the natural ecosystem with introduced pasture, which is currently considered as the only way of increasing productivity.

Table 3. Multi-nutritional blocks with palm oil or solubilized fatty acids for fattening cattle on natural savannah (*Axonopus purpussi*).

Variable	Savannah without block	Block 10% oil	Block 10% SFA	*B. decumbens* without block
Initial LW kg	218	241.9	238.0	
Final LW kg	227.8	270.0	267.7	
LWG g/d	146.2	420.0	443.2	450.0
Additional LWG cp. savannah		237.8	297.0	
Block intake g		215	218	
Cost of block USD		0.045	0.047	
Additional gain USD		0.284	0.356	
Stocking rate/ha	0.22	0.6	0.4	0.8
Meat production kg/ha/month	0.965	7.6	5.3	10.6
Meat production kg/ha/year	11.6	91.2	63.6	129.6

The Savannah System of Pig Production

This work was carried out in the Municipality of Puerto Gaitan, Departmento del Meta, Colombia in the ecological zones of savannah plains and the banks of the river Meta, an area of tropical rainforest with an average annual temperature of 28 deg C, annual rainfall of 1800-2300 mm/year and an altitude of 200 m a.s.l.

Three trials were carried out; each trial corresponded to one phase or cycle of the pigs (Penuela *et al.*, 1996).

Each phase was carried out in an area of 1 hectare, surrounded by a wooden fence with wire netting, divided into 4 equal parts (0.25 ha each) with feeder and water pipe in each corral. Each corral was provided with 16 sq m of shade. The number of animals in each trial varied from 40 to 60 depending on the stocking rate to be evaluated. The treatments (diets) were designed with 2 replicates and 10 animals per replicate.

The treatments applied were (g/animal/day):

	T1	T2
Fortified soya cake[1]	500	500
Rice polishings[2]	200-300	200-300
Crude palm oil[3]	300-500	500-600
Sugar cane (crushed)	ad lib.	-------

[1] 945 g of soya cake + 50 kg tricalcium phosphate + 3 kg salt + 2 kg vit/min premix

[2] 200 g from 20-60 kg LW and 300 g from60 kg until they reached 90 kg

[3] 300 g from 20-60 kg LW and 500 or 600 g from 60 kg until they reached 90 kg

For phase 1 and 2, an adjustment was made to the diets by adding 100g/pig/day of rice polishings and 100g/pig/day of crude palm oil for each treatment respectively.

In the study area (1 ha), the botanical composition and existing soil fauna were examined before the entry of the pigs and once following the completed cycle, as well as monitoring the physical and chemical characteristics of the soil and the performance of the pigs.

The results obtained reflected the biological and economic performance of the pigs at pasture, their behaviour and the changes in soil and botanical characteristics of the study area.

Biological Performance of the Pigs

The results obtained during the three phases of the investigation are summarized in the following table:

Table 4. Average results for fattening pigs

	T1	T2
No. of animals	27	27
Number of days on trial	117	117
Live weight kg		
Initial	36.0	33.3
Final	87.6	85.8
LWG (g/day)	440	448
Intake (kg/day)		
Soya bean meal	0.500	0.500
Palm oil	0.420	0.620
Rice polishings	0.326	0.587
Sugar cane	2.3	0.0
Total DM intake (kg/day)	1.74	1.23
Feed conversion (DM)	3.6	2.7

Source: Penuela *et al.*, 1996.

The average biological results are positive and acquire additional value when it is realized that they were obtained under an open field system (pasture). It could be said that it is difficult to find positive results for fattening pigs in these conditions. The main reason for these good results is due to the use of fatty acids contained in the palm oil, responsible for a high percentage of the energy provided in the diet. It would be difficult to achieve this with cereals as the source of energy.

It is interesting to compare the production of meat from pigs and cattle per unit area under savannah conditions, still with reference to a cattle system based on *Brachiaria decumbens* pastures.

From the experimental results, the production of pig meat per hectare in one cycle is 1,958 kg. If a minimum of two cycles are considered per year, the meat produced rises to 3,916 kg/ha/year. In similar savannah conditions, using improved pastures (*Brachiaria*), cattle produce around 130 kg meat per year.

These results show that there is a much greater range of potential for the use of savannahs, without having to transform all the characteristic conditions of the ecosystem.

Ethology

The following account of the behaviour of the animals was observed:

- At the introduction of the pigs to the experimental area, they began to explore the ground by moving around the whole area.
- The pigs stayed in a group, defined their social organization, established their rank: those which fed first and the lower rank ones which fed second.
- The pigs selected certain places for rooting and used the same place daily so as to convert it into a mud patch.
- Under these conditions, the body condition and health of the pigs was good. It should be noted that no form of medication was used throughout the trials.
- The consumption of water varied over time. On sunny days it was 12 litres/animal/day and 6 litres per day on dull days.
- The pigs consumed various plant species that were available in the experimental field, including mainly: *Salvia palaefolia, Anturium* spp. and *Pueraria phaseloides*.

Monitoring of Physical and Chemical Conditions of the Soil

The physical and chemical conditions of the soil were monitored over a period of 16 months, the time which carried it to the end of three phases of the trial.

Soil analysis showed that the texture was maintained in the range of less than 20% clay and more than 60% sand. The increase in soil organic matter (although small) is significant, considering the short monitoring time and the soil conditions in the region. The tendency is to increase organic matter, a condition which would favour water retention and reduce the impact of the dry season on the soil and production.

With respect to minor nutrients, there were deficiencies of copper and zinc, although the tendency is to increase with time; manganese was within the acceptable range and iron was normal for this type of soil (oxisol). The pH tends to reduce, possibly due to the increase in organic matter.

In general, it can be said that the changes recorded in the experimental area are favourable, however small because of the short timescale, and tending to improve with time.

Biological Activity of the Soil

In order to monitor biological activity of the soil, samples of the invertebrate population were taken periodically throughout the same 16 month period.

Very interesting results were observed in the changes in the invertebrates (Table 5), showing notable differences in the number and diversity of species present in the experimental site, monitored before and after the presence of the pigs, and also according to the season (summer/winter).

More than 9 different species of invertebrates associated with the soil in the experimental area are reported.

To show comparative effects, a control site was established outside the experiment. After a series of samples were taken at the same time as in the experimental area, no associated invertebrates were found.

In general terms, the presence of the pigs increased the biological activity in the study area, in response to the physical disturbance of the soil by the rooting of the animals and a greater supply of organic matter.

Table 5. Invertebrate populations (per sq m)

	1/95	6/95	9/95	12/95	3/96
Earthworms	0	7	99	37+e	102+e
Scarabid larvae	41	20	53		
Adult Scarabids	0	0	0	0	4
Centipedes	0	1	10	6	62
Ants	+	+	++	+++	+++
Termites	0	0	++	+++	+++
Coleoptera	0	0	14	6	91
Hemiptera	0	0	5	0	12
Carabid larvae	0	0	6	4	71
Adult carabids	0	0	0	0	3
Lepidoptera larvae	0	0	7	1	9
Elaterid larvae	0	0	0	0	6
Adult cicindellidae	0	0	0	0	3
Asilid larvae	0	0	0	0	2

+e = earthworm eggs

The results are variable depending on the time of year. In the first sample (January-Summer), no biological activity was found in either the experimental zone or the control site. Different results were found in December, also in summer, when biological activity was shown in the experimental site but not in the control area. The difference appears to depend on the presence of the pigs in the experimental area and the growing biological changes that this initiates in the soil. The greatest biological activity was found in the rainy season (July-September and May) which favoured soil moisture and living organisms in the soil.

Economic Analysis

The profitability per pig in phases 1 (USD 19.3-24.6) and 2 (USD 20.0-26.2) was good. In phase 3 (USD 4.7-8.3), the results were not so favourable as a result of the low level of prices in Colombia which failed to meet the costs of production, possibly due to the market crisis caused by imports of pigmeat from other countries, a problem which was critical to all pig producers at the time.

The biological and economic results are highly relevant, because it is difficult to find such results with out-door pigs. There is an urgent need to confirm the recommendations for this system.

It must be noted that, although the reported profitability is good with respect to pigs alone, it also provides an alternative method of pasture management that does not require high initial capital for installations. Furthermore it does not indicate the other economic and environmental advantages conferred by the presence of pigs. These include the improvement of soil conditions, increase in biological activity, the encouragement of desirable species and the effect on subsequent production.

Pig production based on the system described also plays an important role in furthering the processes of regeneration of pasture and greater capacity for seed development of the species present in the area: the pigs exert a scarifying effect on the seed, increasing its viability. The direction in which this leads suggests a dynamic increase in productivity starting with pigs production, through the greater organic activity which it stimulates to achieve additional benefits in pigmeat production, as well as greater vegetation cover.

Currently, work is in progress to collect the data on agricultural production in areas previously exploited by pigs, and to construct a model for the integral use of natural savannah soils. This will involve crops that are exclusively managed within the concept of organic farming, with a view to implementing a sustainable system with integrated use of resources. The proposed rotations are: pigs-maize-cowpea; african palm-cowpea; and pigs-cowpea-maize-palm. During the establishment of the african palms and throughout their productive life, cowpea and soya are produced in the alleys; the design for this involves the planting of 100 palms per hectare. It is also possible to consider other perennial crops besides palms, with the criterion that they produce biomass which may be included in the pigs' diet.

New Advances in Pig Production

With the help of FAO, two experiments have recently been carried out on the feeding of fattening pigs, incorporating forage sources in the diet as partial substitutes for the protein normally provided by soyabean meal. The diets used have crude african palm oil as the principal source of energy.

The first experiment evaluated the partial replacement (20%) of the protein (200 g/day) by *Azolla filiculoides* and leaves of *Trichanthera gigantea*, as well as offering crude palm oil either ad lib or restricted. Sixteen animals per treatment were used over the complete fattening cycle (126 days).

Table 6. Average results for pigs fed diets with *Azolla filiculoides*, *Manihot esculenta* (cassava) and *Trichanthera gigantea*.

	T1	T2	T3	T4
Live weight kg				
Initial	23.6	24.5	24.2	24.4
Final	86.6	87.5	83.4	87.4
LWG g/day	0.500	0.500	0.470	0.500
Intake kg/day				
Soya bean cake	0.500	0.350	0.350	0.350
T. Gigantea	0.0	1.2	0.0	0.0
Azolla	0.0	0.0	3.0	0.0
Manihot esculenta	0.0	0.0	0.0	1.5
Palm oil	0.450	0.450	0.450	0.450
Rice polishings	0.175	0.175	0.175	0.175
TOTAL	1.125	2.18	3.98	2.48
DM	1.04	1.2	1.05	1.14
FCR (DM)	2.08	2.4	2.23	2.28

Animal performance was slightly better when they were offered leaves of *Trichanthera gigantea* as a substitute for the protein provided by soyabean meal, a very interesting result in relation to the design of integrated production systems in which the tree component plays an important role.

This experiment showed that supplying a higher level of energy from african palm oil (T1 and T4) did not lead to a large response by the animal, but it significantly raised the costs, reduced the quality of the carcass by producing a large amount of fat and affected the feed conversion efficiency. It appears that pigs respond better to an adequate balance of the sources of energy (fatty acids and carbohydrates) that is well provided by the medium treatments (T2 and T3) and the relation between the content and quality of the protein in the diet.

Another experiment, evaluating three forage protein sources as substitutes for 25% of the soya protein (200 g/day) by means of giving Azolla filiculoides (DM 5%, CP 25%), Trichanthera gigantea (DM 25%, CP 18%) or cassava leaves (DM 16%, CP 22%) in a diet based on crude palm oil and a strategic input of rice polishings, demonstrated the viability of introducing forages in diets where the source of energy was principally provided by crude palm oil.

Table 7. Average results for pigs fed diets containing *Azolla filiculoides* and *Trichanthera gigantea*.

	T1	T2	T3	T4
Live weight kg				
Initial	23.9	23.1	23.5	26.2
Final	89.1	80.1	82.8	93.1
LWG g/day	0.517	0.453	0.470	0.530
Intake kg/day				
Soya bean cake	0.400	0.400	0.400	0.400
Azolla	1.6	1.9	0	0
T. gigantea	0	0	1.0	1.0
Palm oil	1.3	0.450	0.450	1.3
Rice polishings	0.200	0.200	0.200	0.200
TOTAL	3.3	2.95	2.05	2.9
DM	1.85	1.06	1.21	2.02
FCR (DM)	3.5	2.33	2.57	3.82

Animal performance was not affected by substituting 25% of the traditional protein. It is particularly attractive to use the leaves of cassava which can be done as an integral use of this resource during the growing stage of the crop.

In all cases, excluding feed conversion efficiency, the results were as good as those given by the standard recommendations for pigs based on cereals and traditional sources of protein, with total inputs far higher than those reported here. In this sense, the concentrated input of energy in the form of fatty acids (african palm oil) performs a strategic role in the feeding system that is proposed.

These alternatives permit the pig producer to achieve a good level of integration of production and, at the same time, a greater independence from external factors and inputs to the system, which allows greater economic sustainability and productivity. This tendency can be even better when the production of the oil palm is included as the central energy component of the production unit, achieving a higher level of autonomy in the production cycle and allowing a growing level of integration.

Finally, it is important to point out the simplicity of the proposed feeding system, which can be implemented by any producer without the need for special equipment or machinery. Also, when offering this kind of diet, it is possible to carry out the management operations on the pigs in the morning only.

Advances in Fattening Broilers

Having in mind the design of a feeding system for fattening broilers in semi-confinement associated with established perennial crops, a system has been evaluated which uses crude palm oil as the basic energy source together with fortified soyabean meal (soyabean meal 97.5%, tricalcium phosphate 2%, mineral/vitamin mix 0.3% and sodium hydroxide 0.2%) as the protein source (Ocampo *et al*., 1995; Ocampo *et al*., 1996).

The birds were managed in the traditional commercial way up to the third week, when they received a commercial concentrate, and were housed in confinement with heating. From the fourth week, they were offered the experimental diet and the birds went out to pasture between the trees.

Two types of diet were evaluated initially: diet A which consisted of a 1:1 mixture of crude palm oil and soyabean meal fortified with minerals and vitamins, with a maximum intake equivalent to 70% of the expected consumption on commercial diets (determined from 3 initial experiments) and diet B which included a 1:1 mixture, of which one part consisted of 80% palm oil and 20% rice polishings and the other part of fortified soya with minerals and vitamins, offered *ad libitum*.

Following a total period of 49 days, the results were as follows: Diet A - mean final weight 1,939 g, cumulative FCR 1.68, killing-out percentage 78.55, with average daily intake of 539 g; Diet B - mean final weight 2,016 g, FCR 1.64, KO% 75.4 and daily intake 604 g.

After that, *Azolla filiculoides* was included in the diet to appetite with the birds allowed to adjust their protein intake on a free-choice basis. Azolla was offered fresh after a period of draining for 3 hours after harvesting.

The diets A and B remained in the design and only the addition of Azolla was different. The results were as follows: Diet A - final weight 1,804 g, FCR 1.79, KO% 75, intake of supplement 500 g and intake of Azolla increasing from 40 to 163 g/bird/week; Diet B - final weight 1,963 g, FCR 1.77, KO% 76, intake of supplement 698 g and intake of Azolla from 39 to 176 g/bird/week.

The results with fattening broilers have been good, it being important to note that the birds were at pasture from the start of the fourth week, which is interesting from the point of view of integrated systems. As a result of the management given, the welfare of the animal was evident; the birds not only performed well in biological and economic terms but it was possible to achieve this with a happy chicken!

Results with Hair Sheep

Finally, it is interesting to relate the results of an investigation with hair sheep as the focus of the basic production system (Ocampo A, Monje S and Pineda C, 1996).

In order to understand the results, the components of the system are presented: the inputs, by-products and outputs from the system.

Components: total area 4,828 sq m (3,264 sq m under shade and 1,564 open), duration of study 405 days, 54 trees of the species *Erythrina poeppigiana*, *Brachiaria decumbens* pasture, 10 ewes and 1 ram, a building and standard sheep management.

Inputs: 860 kg high energy blocks (with 10% palm oil similar to those described for cattle), labour, 8900 litres of drinking water, and 3,240 kg rice husk bedding.

By-products: 4,131 kg organic compost from the floor of the building, which had a contribution of organic matter of 1,367 kg, sheep manure 233.8 kg, plant material not consumed by the sheep 503.5 kg, biomass production from *Erythrina* leaves 629 kg (equivalent to 31.6 kg protein) and 2,230 kg of *B. decumbens*.

Output: 286 kg sheep meat and their skins.

If the meat producing capacity per unit area from the proposed system and the farm is analysed, the benefits are obvious: hair sheep system 42.3 kg/ha/month and 507 kg/ha/year; beef system 13.75 kg/ha/month and 165 kg/ha/year. The production is significantly higher with the hair sheep. This demonstrates the possibility that small and medium sized producers could really achieve high levels of profit from hair sheep and that it is made possible as a result of integration of the different components within the production unit.

Conclusions

There are good opportunities to achieve high levels of production in tropical countries based on the growing of oil palm, which particularly favours a high degree of integration within the production unit and with diversification as a basic factor.

This line of research is likely to lead to the incorporation of trees and perennial crops, and to the better utilization of biomass due to improved energetic efficiency and the exploitation of biodiversity and integration, allowing tropical countries to capitalize on their comparative advantage and evolve more efficient production systems.

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