CASSAVA ROOT AND LEAF MEALS AS THE MAIN INGREDIENTS IN POULTRY FEEDING: SOME EXPERIENCES IN COLOMBIA

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ABSTRACT

Cassava roots provide usable feed energy, while cassava leaves provide fiber and protein. In a conventional cassava crop, the root to leaf ratio as dried ingredients offers a balanced mixture (10:1) to optimize their inclusion in swine and poultry diets. In a non-conventional crop, root or leaf production can be directed to maximize either energy or protein/fiber depending on the final use as ruminant or monogastric feeds.

Cassava root meal can be used to substitute the total energy needs in swine and poultry feeds. This type of diets requires a protein and essential fatty acid supplementation, which can be provided by full-fat soybeans. Cassava root meal mixed with full-fat soybeans becomes an excellent feed to cover the nutritional needs of energy, aminoacids and essential fatty acids for swine and poultry. High performance diets can contain up to 95% of a cassava root, cassava leaf and full-fat soybean mixture.

Pig pre-starter and starter diets may be based on cassava root meal and full-fat soybeans. Growing and finishing diets can contain up to 10% cassava leaf meal in addition to root meal and soybeans. Higher (15%) leaf meal inclusion may be provided during gestation and lactation. On-farm equipment to process cassava and full-fat soybeans has been developed in Colombia as a practical tool for farmers in order to obtain the total energy and protein sources for animal feeds at the farm level. Raw cassava and soybean contain anti-nutritional factors (cyanides and antitripsins), which are destroyed by heat through processing using semi-industrial equipment.

INTRODUCTION

The animal production sector in Colombia is an economic activity with great development potential. During the last decade, this sector, especially the poultry production area (eggs, chicken), has had a dynamics of constant growth that has converted it into an efficient source of animal protein at low cost. Today, at the beginning of the third millennium, the poultry industry in Colombia is one strategic sector that provides the country with food security, employment and income.

Despite the increased growth of the poultry sector in the last decade, there are profound structural problems that affect this activity and that are limiting its contribution to the generation of employment, expansion of the agricultural frontier, technological modernization, exports and even the strategic goal of producing chickens and eggs at lower costs to attend the increasing food needs of the Colombian population.

Among these problems, the principal one is the dependency of imported raw materials that accounts for 80% of the total raw materials used. In a tropical country like Colombia, the poultry production sector is not tropicalized, which means that it is not working with raw materials that are produced under the specific conditions of the country. This situation creates a heavy dependency on imported products to produce the animal feed concentrates. The maize crop is the best example. During the last two years, the amount of maize

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imported for the animal and balanced feeds sector has reached the level of 2 million tonnes per year. The national production is not capable of attending the increasing demand, also affected by the increasing demand for human consumption. Under these circumstances, the steady, increasing growth tendency of the Colombian poultry sector offers the possibility of implementing an agricultural development policy based on the intensified production of raw materials that can be used as substitute of imported cereals like maize. Cassava is one of the crops best suited for expanding the agricultural frontier and at the same time, offers an alternative to the animal and balanced feeds industries. This paper describes some policies that have been implemented recently in Colombia, with the aim of promoting a more intensive use of cassava roots and leaves in balanced feeds for poultry and swine.

The Poultry Sector in Colombia

The poultry sector in Colombia generates approximately 170,000 permanent direct jobs per year, including poultry producers that produce their own balanced feeds, egg hatcheries, egg producers, broiler and reproduction poultry farms, processing plants, and distribution and commercialization points and networks. If the backward and forward linkages of the poultry sector with other sectors are included, such as the production of raw materials (soybean, sorghum, maize), the poultry chain generates more than 300,000 direct jobs per year. The poultry sector in Colombia has been presenting a steady growth during the last decade. In 1999, its contribution to the Colombian GNP was 5.1 times greater than that of the plantain/banana sector and 1.45 times greater than that of the coffee sector (**Figure 1**).

These impressive trends are a consequence of various factors, among which could be mentioned the increased urbanization and the changes that this rural to urban migration causes in the nutritional habits of the population. Traditional foods are replaced by processed, convenience foods that are more easily obtained in urban areas. For example, in just about every corner of the cities, it is possible to find small grocery stores that sell eggs and chicken. The consumption of these two items has been growing steadily during the last two decades (**Figures 2** and **3**).

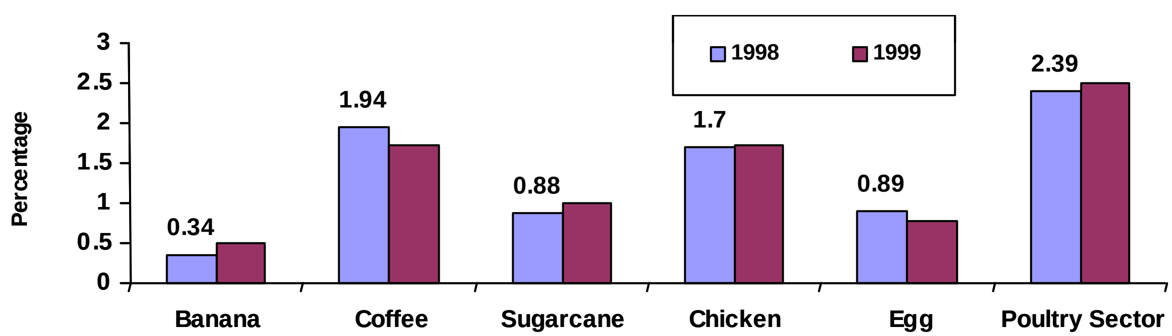

Figure 1. Contribution of some agricultural activities to Colombia's total GNP.
***Source:** FENAVI-FONAV- Economic Studies Program.*

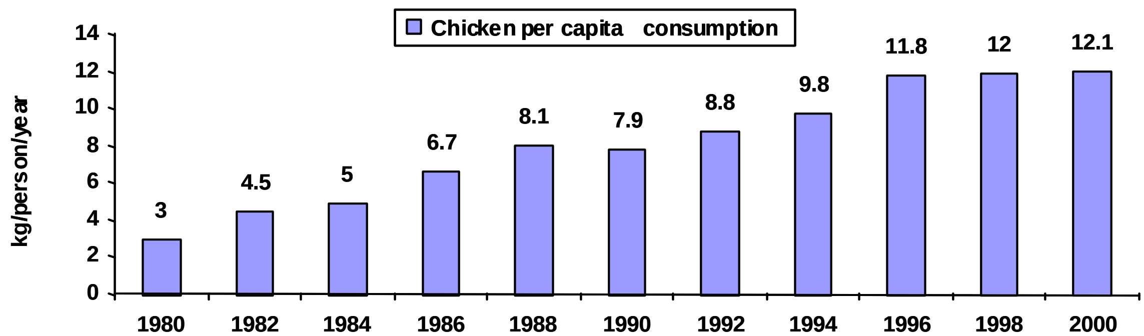

Figure 2. Per capita consumption of chicken in Colombia: 1980-2000.
***Source:** FENAVI-FONAV- Economic Studies Program.*

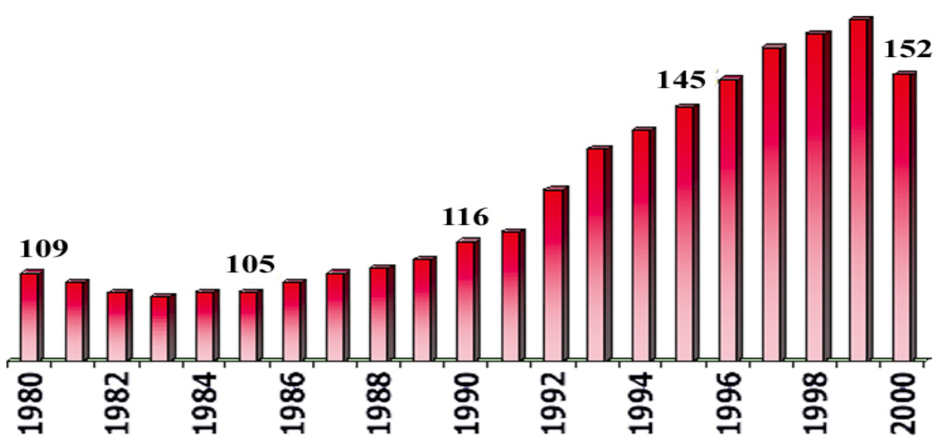

Figure 3. Per capita consumption of eggs in Colombia: 1980-2000.
***Source:** FENAVI-FONAV- Economic Studies Program.*

The poultry sector (eggs, chicken) is affected by some problems that pose a great risk for the continuous development of the activity. The principal risk is related to the dependency on imported raw materials for the production of the balanced feeds that are needed in the production of chickens and eggs. For example, in the total cost of production of one egg, nearly 70% is represented by the cost of maize. The importations of maize in Colombia are now reaching the level of more than 2 million tonnes per year (**Figure 4**).

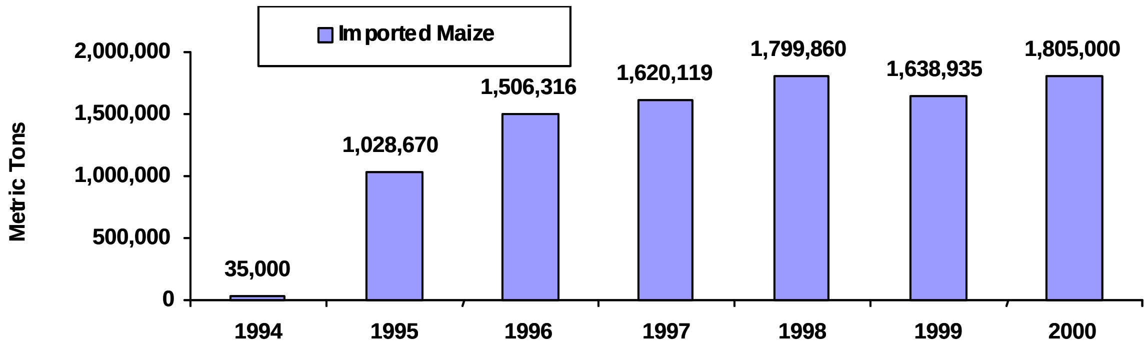

Figure 4. Maize imports in Colombia. 1995-1999.
Source: *FENAVI-FONAV- Economic Studies Program.*

This situation has motivated the poultry sector to look for alternative options that can help them to reduce the dependency on imported cereals. Cassava appears to be one of the most promising alternatives. The sector has called this movement, the "tropicalization of the poultry sector in Colombia". In this context, tropicalization is understood as the promotion and intensification of the use of raw materials that can be produced locally, such us cassava and sweet potato.

The Balanced Feeds Sector in Colombia

The production of balanced feeds in Colombia has experienced a very dynamic growth during the last two decades as a consequence of the increasing demand. **Table 1** presents data on this evolution. It can be observed that on average, growth rates were around 5% per year. From 1990 to the year 2000, the size of the market increased by 50%. This growth has also contributed to the increasing dependency on imported grains to satisfy the requirements for raw material, especially maize (**Figure 4**)

The Market for Cassava in the Balanced Feeds Industry in Colombia

Cassava has a great potential to be developed in Colombia and other countries in the region as a raw material for the growing balanced feed industry. Factors such as the positive growth rates of the sector during the last two decades, the increasing dependency on imported grains to meet this demand for raw materials and the low productivity of domestic cereal production, create an excellent opportunity for cassava to be used intensively as an energy component in animal nutrition programs. The substitution of maize by cassava in balanced feeds for animals is a well-known practice that has had good experiences in many countries such us Holland. **Table 2** shows a typical example of an alternative diet for poultry, based on the partial substitution of maize by cassava flour. The data presented in **Table 2** indicates the potential of the market for cassava flour in the balanced feeds industry. An increment in the use of cassava flour from 0 to 20% in poultry diets implies a reduction of 40.7% in the amount of maize used in the balanced diets.

Table 1. Evolution of the balanced feeds market in Colombia and projections up to 2010 (average for 4 year periods).

Years	Broilers (t/year)	Layers (t/year)	Pigs (t/year)	Cattle (t/year)	Others (t/year)	Total (t/year)
1990/93	942,839	688,941	329,462	154,298	210,450	2,325,990
1994/97	1,198,317	822,853	361,482	157,653	284,401	2,824,706
1998/01	1,453,004	909,686	395,465	170,956	343,067	3,272,178
2002/05*	1,777,968	1,082,971	472,472	202,550	414,428	3,950,389
2006/09*	2,161,131	1,316,358	574,293	246,201	503,740	4,801,723
2010*	2,437,858	1,484,914	647,829	277,726	568,242	5,416,569

*estimates

Source: *FENAVI-FONAV- Economic Studies Program*

Table 2. Balanced feeds for poultry with 20% cassava root flour substituting for maize.

	Broilers		Layers	
Raw Material	Commercial	20% cassava	Commercial	20% cassava
Maize	60.4	35.8	60.4	35.9
Cassava root flour	0	20.0	0	20.4
Soybean cake	11.6	8.9	20.4	17.1
Full-fat soybean	24.8	32.2	8.3	16.3
Oil	0	0	0	0
Carbonate	1.2	1.0	8.7	8.5
Calcium phosphate	1.3	1.3	1.6	1.6
Salt	0.35	0.35	0.35	0.35
Methionine	0.19	0.18	0.14	0.16
Vitamins, mineral additives	0.20	0.20	0.10	0.10

Source: *FENAVI-FONAV- Economic Studies Program*

Potential for the Use of Cassava in the Animal and Balanced Feed Industries in Colombia

Total production of balanced feeds for animal consumption in Colombia for 2000 was estimated at 3,800,000 tonnes. Annual growth of this sector has been around 4 to 5%, thus creating a great pressure on the supply of raw materials, especially agricultural products such us maize, soybeans and sorghum. National agricultural production of these grains has not been able, and will not be able, to satisfy this increasing demand. The principal deficit occurs in the need for energetic sources of which maize and sorghum account for 50 to 60% of the total final volume of balanced feed. Considering the estimations of future growth for the balanced feed sector in Colombia (**Table 1**), it can be concluded that the demand for maize and sorghum in the coming years will be around 2,200,000 tonnes per year. National production with the current areas planted for both cereals will not be able to contribute more than 600,000 tonnes. The difference will have to be imported from countries that have more competitive production systems.

The dry matter content of cassava roots fluctuates normally between 35 and 38%, which is equivalent to a conversion factor of 2.6 tonnes of fresh roots to obtain 1 tonne of cassava flour. Considering a substitution rate of 20% in animal feed concentrates for monogastrics, the needs for cassava flour in Colombia would be around 800,000 tonnes per year. If we consider a range of 15-30 t/ha as the average yield, then Colombia will need to plant approximately 70,000 to 140,000 new hectares of cassava to satisfy this demand.

Cassava leaves can also be processed to produce cassava leaf flour with a high level of protein and fiber for use in animal feeding. One hectare of cassava, with sound management, could yield both roots and leaves or top parts that can be processed into balanced feeds. This cassava leaf flour has also a good potential for feeding ruminants due to its high fiber content. In feeding monogastrics, its use is more limited due to the low level of energy and high fiber content.

Intensive use of cassava in animal feeding requires the elimination of anti-nutritional factors such as linamarine in cassava roots. This compound acts as a precursor of hydro-cyanic acid. The use of adequate processing methods is sufficient to eliminate this problem. The roots have to be properly dried to a moisture content of 12-13% using processing technologies that allow the elimination of the cyanide. In general, it is considered that a level below 100 ppm of hydro-cyanic acid in the final product (cassava flour) is safe for use in animal feed diets.

Cassava flour can be used to partially substitute cereals used in animal feeding for the different species (poultry, swine, cattle, fish). When the proper nutritional adjustments are made in the diet that contains cassava products, the performance of the animals is comparable with the performance obtained in animal feeding programs based on cereals. Most of the research that has been conducted in the world on this subject indicates that cassava flour can be used in levels between 20-40% in the total diet for poultry and swine.

The principal characteristic of cassava flour is the high carbohydrate content (starch) that gives an energy level slightly lower than that of maize and sorghum. The principal limiting nutritional factor in cassava is its low content of protein (2.5-3.5%) and essential fatty acids (< 1.0 %), in contrast with maize and sorghum. Due to these limitations, the price of cassava flour is generally around 70-75% in relation with the price of maize. The difference in price allows the poultry, swine or balanced feed producer to supplement the diet with sources of protein and fat such as soybean. A moderate amount of soybean (full-fat or extruded) can supplement all the nutritional deficiencies of cassava when used in animal feeding programs. The other product of cassava, the leaves, is characterized by their high protein content (18-22%) and fiber content (25-30%). Depending on the animal to be fed, cassava can be used as a partial substitute of cereals, contributing protein, fiber, minerals, vitamins and energy (**Table 3**).

Table 3. Maximum levels of inclusion of cassava roots and leaves in animal balanced feed for various animals.

	Level of inclusion (%)	
Animal	Cassava roots	Cassava leaves
Poultry	25-40	6-8
Pigs	40-80	8-10
Horses	30	
Fish	25	8
Cattle	100	100

Experiences with the use of Cassava Flour in Animal Feeding in Europe

The use of cassava flour in animal feeding started at a commercial level in the 1970s when Thailand launched an aggressive program to produce and export cassava chips to European markets. These programs were built with a very heavy component of subsidies to establish the infrastructure needed to take advantage of this new market. Roads and ports were built, and cassava farmers had access to technical assistance, credit and subsidies to produce and process the crop. The main consumer for these cassava chips and pellets exported from Thailand have been countries in the European Union, especially Holland. In 1970, about 1 million tonnes of cassava flour and pellets were exported from Thailand to the EU, and Holland alone was responsible for using 76% of this volume. By 1980, the volumes exported had grown almost six times and Holland was responsible for consuming 70% of the total volume. Finally, by the year 2000, the volumes of cassava exported had decreased to 4.2 million tonnes and Holland was consuming almost half of the total. This reduction in imports was due to agricultural policies aimed at reducing the financial resources (subsidies) spent on agriculture in the EU and the need to increase the prices for cereals produced in the EU (**Table 4**).

Table 4. Imports of cassava flour and pellets from Thailand into Europe.

	1970	1978	1999
		('000 tonnes)	
European Union	1,000	5,962	4,269
of which Holland	760	4,261	2,429

Source: *Van Poppel, 2001.*

The massive use of cassava flour and pellets by the animal feed and animal production industries in Holland is based on the fact that one kg of cassava flour yields 7% more energy than 1 kg of barley, but 10% less than 1 kg of maize. However, the international price of cassava is 8% cheaper than the price of maize. With this difference in prices, the computer-based models used for calculating the diets prefer to include cassava instead of maize. For the last 40 to 50 years, in Holland, maize has not been included in swine feeding programs because the extra nutritive values that maize could give is not compensated for by the higher price of this cereal. In poultry feeding, cassava flour has 4% less energy than wheat and almost 11% less than maize, but today, with the current prices of maize and wheat in the international markets, the balanced feed industries in Holland use between 10 and 15% of cassava in the formulations. Maize is not used because it is very expensive. Another aspect that explains this preference for cassava is that consumers prefer a chicken with less yellow skin. The option has been to develop feeding systems in which maize only enters at 5% and the ration is based mainly on the combination of wheat and soybean (**Table 5**).

Table 5. Maximum levels of inclusion of cassava flour and pellets in animal feeding in Holland.

Type of animal	% of inclusion
Swine - raising	20
Swine - fattening	40
Swine - reproduction	40
Poultry - broilers	20-25
Poultry - eggs	30% pellets, 15% flour

Source: *Van Poppel, 2001.*

Experiences with the Use of Cassava Flour in Animal Feeding in Colombia.

In Colombia, the use of cassava in animal feeding has been practiced during the last 30 years. However, the volumes used do not match the tremendous market potential that the balanced feeds sector offers. Among the reasons for this is the unreliable supply of cassava root flour and chips which does not make it attractive for the animal and balanced feed producers to change constantly their formulations. This limitation is now being tackled through government-supported programs that consider cassava as a strategic crop. These strategies will promote considerable increases in the area planted and the volumes processed during the next five years. Another reason for the relatively low use of cassava products in animal feeding in Colombia and other countries of Latin America is the lack of knowledge, dissemination and diffusion, throughout the region, of successful experiences on the use of cassava in animal feeding. CLAYUCA is trying to contribute to solve this constraint through the implementation of experimental work that helps to validate the information available and disseminates the results widely among interested parties. The next section presents some of the preliminary results obtained by CLAYUCA.

Levels of Inclusion of Cassava Flour in Poultry Balanced Diets

The use of cassava, both roots and foliage, in poultry feeding programs is affected by external and internal factors. The most important external factors are: the age of the animal, the type of processing (milled, pelleted, crombelized, extruded, etc) of the final product, and the complementary ingredients that will be included in the diet. The internal factors are related principally to the quality, availability and price of the products. The processing system is one of the external factors that influences the level of cassava that can be used in the diet. Cassava flour, for example, is a rather dusty product that causes management problems when it is mixed with other products and given to the animals. To counteract this limitation, the maximum level of cassava for inclusion in poultry diets is around 25 to 30%. If higher levels are used, then oil or sugarcane molasses have to be used to reduce the dusty characteristic of the diet. If the diet is prepared in the form of pelleted, crombelized or extruded products, higher levels of cassava can be used.

In the case of cassava foliage flour, the most limiting external factor is the fibrous characteristic of the foliage, a constraint that does not allow the inclusion of levels higher than 6 to 8% in the final diet. Even with these low levels, the inclusion of cassava foliage in poultry diets gives an important contribution of protein and natural pigments for both broilers and layers.

Complementarity of Cassava and Soybeans in Poultry Feeding Programs

When cassava root flour is used to prepare a balanced feed, due to its lack of protein and some essential fatty acids, it needs to be complemented with other ingredients that provide the nutrients needed for the feed to be appropriately balanced. Integral soybean (full and fat) has a good synergy with cassava in the design of poultry feeding programs with high nutritional quality. A balanced mixture of cassava flour and integral soybeans can totally cover the requirements for energy, protein and essential fatty acids for broilers and layers.

As shown in **Table 6**, the low concentration of some essential nutrients present in cassava root flour can be compensated satisfactorily by including soybeans in the balanced feed. The specific nutritional requirements for both layers and broilers can be fully satisfied by different mixtures of cassava flour (from roots and leaves) and integral soybeans. The complementarity between the two crops simplifies the design of sound animal nutrition programs under commercial conditions. A mixture of 82 parts of cassava root flour and 18 parts of integral soybean, becomes a product with similar characteristics to those of cereals (**Table 7**)

Table 6. Main nutrients in cassava flour and integral soybeans.

Nutrient	Unit	Cassava root flour	Cassava foliage flour[1)]	Integral soybean
Metabolizable energy	Mcal/kg	3.0 to 3.2	1.38	3.6 to 3.8
Starch	%	68		8.0
Protein	%	2.8	20.7	38.0
Fiber	%	2.6	15.2	4.9
Ashes	%	3.2	8.5	5.2
Fat	%	1.2	5.3	19.0
Linoleic acid	%	0.4		8.9
Lecitin	%	0.1		2.0
Methionine	%	0.03	0.36	0.51
Cystine	%	0.02	0.60	0.60
Lysine	%	0.05	1.87	2.31
Threonine	%	0.05	1.35	1.43
Tryptophane	%	0.02	0.24	0.52

[1)] Includes leaves, petioles and young stem, harvested at 3 months after planting.

Sources: *Van Poppel, 2001; Buitrago and Luckett, 1999.*

Table 7. Nutritional composition of cassava flour (82%) mixture with integral soybeans (18%) as compared to that of maize.

Nutrients	Cassava flour (82%) + integral soybean (18%)	Commercial maize
Metabolizable energy, Mcal/kg	3.25	3.34
Protein, %	9	8.5
Lysine, %	0.46	0.26
Methionine, %	0.12	0.18
Methionine + cystine, %	0.24	0.35
Threonine, %	0.28	0.29
Thryptophane, %	0.10	0.07
Arginine, %	0.51	0.40
Fat, %	3.5	3.6
Linoleic acid, %	1.7	2.1
Fiber, %	3.9	2.8
Ash, %	3.6	2.1
Calcium, %	0.29	0.04
Available phosphorus, %	0.09	0.08

Source: *Buitrago and Luckett, 1999.*

Experiences obtained in Colombia using this type of feed (mixture of 82% cassava flour and 18% integral soybean) have shown the possibility of obtaining performances that are similar to those obtained with diets elaborated using traditional cereals (maize and sorghum). Some results obtained in poultry feeding programs based on mixtures of cassava flour and processed integral soybeans are discussed in the next section.

Broiler Feeding Programs Based on Cassava and Soybean Mixtures

Balanced feed for broilers is generally prepared in the form of pellets or crombelized diets so the dustiness of the cassava flour is not a limitation; and the recommendation for the level of inclusion of cassava roots that can be used could be as high as the total substitution of cereal grains in diets for starting and finishing broilers. This type of diet allows the inclusion of the maximum levels of cassava root flour (45-50%) and cassava foliage flour (5-6%). If there is ample availability of these ingredients (cassava root flour, cassava leaf flour, integral soybeans and soybean meal) at competitive prices, it is possible to formulate a perfectly balanced diet for broilers, in which these four ingredients represent up to 95% of the total feed, as illustrated in **Table 8**.

Results of Feeding Programs for Broilers with Maximum Levels of Inclusion of Cassava Flour

CLAYUCA has conducted recently some work with financial support from FENAVI, the Colombian Poultry Growers Federation, and the Colombian Ministry of Agriculture and Rural Development. The objective was to evaluate the technical and economic feasibility of using diets similar to those presented in **Table 8**. The diets were prepared with total replacement of maize using cassava flour from roots and foliage and integral soybeans. The check was a commercial feed based on maize and integral soybean. The preparation of the cassava root flour was done using two processing methods: solar drying on cement floors and artificial drying using a pilot plant available at CLAYUCA, that uses steam to heat the air. **Table 9** presents the detailed composition of the four diets used.

Table 8. Example of a complete ration for broilers based on cassava products and integral soybean.

Ingredients, %	Starter		Finish	
	Roots	Roots and foliage	Roots	Roots and foliage
Cassava root flour	45.7	40.4	49.8	46.0
Cassava foliage flour		6.0		6.0
Integral soybean (toasted)	30.0	30.0	41.6	45.1
Soybean meal	18.7	16.4	5.2	
Palm oil	2.9	4.5		0.3
DI-methionine	0.29	0.29	0.23	0.23
Dicalcium phosphate	1.52	1.52	1.52	1.5
Calcium carbonate	0.38	0.38	0.38	0.32
Salt	0.3	0.3	0.3	0.3
Vitamins and minerals	0.1	0.1	0.1	0.1
Anticoccidial and additives	+	+	+	+
Nutritional composition				
Metabolizable energy, Mcal/kg	3.22	3.22	3.18	3.18
Protein, %	22.00	22.00	20.00	20.00
Methionine, %	0.59	0.59	0.49	0.49
Methionine + lysine, %	0.90	0.90	0.78	0.78
Lysine, %	1.26	1.26	1.12	1.12
Linoleic acid, %	3.41	3.56	3.60	3.85
Calcium, %	0.91	0.91	0.96	0.90
Availabe phosphorus, %	0.42	0.42	0.40	0.40

***Source**: Gil et al., 2001.*

1. Effects on weight gain and feed conversion

Table 10 shows the performance of the broilers during the first 42 days when the trial was finished. It can be noticed that every group that consumed cassava flour and integral soybeans had a weight gain and feed conversion similar or superior to the control group fed with the commercial diet based on maize and integral soybeans. The consumption of the balanced feed was not affected by the treatments that included high levels of cassava flour. The mortality rates were the same in all the treatments. The performance of the chickens was superior when the cassava root flour was prepared using the artificial drying system, suggesting a positive effect from this processing method. The high temperature and the better sanitation control that is obtained with the artificial system could explain this positive effect.

Table 9. Diets based on cassava root and leaf flour in comparison with a maize-based control diet for broilers - Starting Phase.

Ingredients, %	Control	Cassava root flour Solar drying	Cassava root flour Artificial drying	Cassava root flour + foliage flour
Maize	59.37			
Cassava root flour		45.75	45.75	40.45
Cassava foliage flour				6.00
Integral soybean	12.80	30.00	30.00	30.00
Palm oil	3.00	2.90	2.90	4.50
Soybean meal	21.00	18.70	18.70	16.40
DI-methionine	0.16	0.29	0.29	0.29
L-Lysine	0.07			
Bone meal	1.70	1.90	1.90	1.90
Calcium carbonate	1.50			
Salt	0.30	0.30	0.30	0.30
Vitamins and minerals	0.10	0.10	0.10	0.10
Nutritional composition				
Metabolizable energy, Mcal/kg	3.20	3.20	3.20	3.20
Protein, %	22.00	22.00	22.00	22.00
Methionine, %	0.59	0.59	0.59	0.59
Methionine + Cystine, %	0.90	0.90	0.90	0.90
Lysine, %	1.26	1.26	1.26	1.26
Linoleic acid, %	2.62	3.42	3.42	3.56
Calcium, %	0.91	0.91	0.91	0.91
Available phosphorus, %	0.42	0.42	0.42	0.42

2. Effects on pigmentation

Important observations were made in relation with the degree of pigmentation of the skin, legs and internal fat of the birds. The groups with diets based on cassava root flour were characterized by a poor pigmentation throughout the experiment. However, the group with a diet based on cassava root and cassava foliage flours had a pigmentation similar to that of the control group fed with diets based on yellow maize. The visual appreciation on a scale from 1 (more pale) to 5 (more pigmented), gave these two groups a score of 4, whereas the groups fed with only cassava flour obtained a score of 2.

Results of Feeding Programs for Broilers with Medium and Low Levels of Inclusion of Cassava Flour

Although the results obtained from replacing totally the cereal grains by cassava flour in pelletized diets have demonstrated the viability of this practice in commercial feeding programs for broilers, it is possible that in many occasions it is more convenient to use a partial substitution of the cereal grains. This partial substitution could be even more important when the diets are prepared in the form of flour given the dusty characteristics of cassava flour.

Table 10. Performance of broilers up to 42 days fed with cassava root flour dried using three different methods.

Parameter	Control	Cassava root flour			Cassava root flour and foliage flour
		Solar	Equipment A	Equipment B	
Initial weight, g	39.80	39.50	39.40	39.50	39.70
Final weight, g	2.14	2.28	2.24	2.39	2.11
Consumption, kg	4.73	4.88	4.65	4.68	4.72
Efficiency of feed conversion	2.21	2.14	2.08	1.96	2.24

Tables 11 and **13** show the composition of diets with intermediate levels of cassava flour, so as to substitute 50% of the sorghum and maize, respectively, used in diets for the starting and finalization phases of broiler feeding. The results obtained are shown in **Table 12** and **14**. It can be observed that, in general, the broilers that consumed diets with 50% substitution of sorghum or maize performed equal or better than those broilers fed with the conventional diets based on sorghum or maize. In terms of weight increase, the feed conversion ratio and carcass yield did not present significant differences either. Adverse effects of the inclusion of cassava flour in terms of mortality or morbidity were not observed.

Table 11. Diets for broilers with intermediate levels of cassava root flour to replace 50% of sorghum.

Ingredients, %	Starter	Finish
Sorghum	33.65	33.61
Cassava root flour	20.00	25.00
Toasted integral soybean	32.00	34.00
Soybean meal	8.20	2.80
Fish meal (65%)	3.50	4.00
Palm oil		0.10
Dicalcium phosphate	0.90	0.70
Calcium carbonate	0.80	0.90
Dl-methionine	0.27	0.22
Salt	0.25	0.25
Choline chloride (50%)	0.12	0.10
Vitamins and minerals	0.10	0.10
Anticoccidial	0.10	0.10
Fungicide	0.10	0.10
Nutritional composition		
Metabolizable energy, Mcal/kg	3.15	3.20
Protein, %	21.00	19.00
Methionine, %	0.58	0.51
Methionine + Cystine, %	0.88	0.77
Lysine, %	1.23	1.10
Thryptophane, %	0.28	0.25
Threonine, %	0.60	0.59
Linoleic acid, %	3.08	3.10
Calcium, %	0.90	0.91
Available phosphorus, %	0.43	0.40

Source: *Buitrago and Luckett, 1999.*

Table 12. Performance of broilers fed with sorghum or with an intermediate level of cassava root flour in the diet.

Parameters	Check [1)]	Cassava root flour + integral soybean[2)]
Starting number	48.441	24.000
Finalizing number	46.199	22.392
Number of days	42	42
Mortality, %	4.6	6.7
Final weight, g	1,934	1,915
Feed consumption, g	3,559	3,152
Feed conversion ratio	1.84	1.69
European efficiency factor	239	259

[1)]100% sorghum as main feed ingredient
[2)]50% of sorghum replaced by cassava root flour and integral soybean
Source: *Buitrago and Luckett, 1999*

Table 13. Diets for broilers with intermediate levels of cassava root flour to replace 50% of maize.

Ingredients %	Starter	Finish
Maize	25.34	30.79
Cassava flour (82%) + soybean (18%)	30.50	30.50
Toasted integral soybean	25.90	28.30
Soybean meal	12.10	4.80
Chicken innards meal	3.00	3.00
Dicalcium phosphate	1.30	1.00
Calcium carbonate	1.00	0.90
Dl-methionine	0.23	0.10
Salt	0.35	0.30
Vitamins and minerals	0.12	0.10
Anticoccidial	0.05	0.10
Fungicide	0.10	0.10
Nutritional composition		
Metabolizable energy, Mcal/kg	3.10	3.20
Protein, %	22.00	17.00
Methionine, %	0.56	0.40
Methionine + Cystine, %	0.90	0.72
Lysine, %	1.24	1.10
Thryptophane, %	0.28	0.25
Threonine, %	0.80	0.75
Linoleic acid, %	3.25	3.48
Calcium, %	0.90	0.82
Available phosphorus, %	0.42	0.39

Table 14. Performance of broilers fed with maize or with an intermediate level of cassava root flour in the diet.

Parameters	Check[1)]	Cassava root flour + integral soybean[2)]
Starting number	7,680	7,673
Finalizing number	7,415	7,108
Number of days	42	42
Mortality, %	3.2	5.7
Final weight, g	1,976	1,942
Feed consumption, g	3,754	3,781
Feed conversion ratio	1.90	1.94
European efficiency factor	239	218

1) 100% maize as main feed ingredient
2) 50% of maize replaced by cassava root flour and integral soybean
Source: *Buitrago and Lucket, 1999.*

Feeding Programs for Layers Based on Cassava and Soybean Mixtures

Feeding programs for layers generally involve the use of diets in flour form, which becomes an important limitation for the inclusion of high levels of cassava root flour. To overcome this limitation, low and intermediate levels of cassava root flour are used. Unless pelletized or crombelized diets are used, it is difficult to incorporate cassava flour in the diets with levels higher than 25%. The dusty nature and the high starch content of the cassava root flour make it difficult to manage higher levels of cassava root flour in the balanced feed.

With respect to cassava foliage flour, it is recommended that the maximum level to be used in diets is around 5 to 6%, to minimize the effects of the low palatability of the feed. Likewise, the energy concentration of the diet makes it difficult to include higher levels. When levels of 5 to 6% of cassava foliage flour are used, a good pigmentation is obtained in the egg's yolk due to the presence of natural xanthophylls in the cassava foliage.

Results of Field Experiences

The following results are a summary of experiments conducted in several regions of Colombia, at commercial scale, and using different stages of production, diets, raw materials and nutritional parameters. In all cases, the diets were prepared in the form of flour. **Tables 15** and **17** illustrate the composition of the diets used. **Tables 16** and **18** present the results obtained in the different trials.

No important differences were observed in the production parameters evaluated: egg laying percentage and conversion efficiency. The results obtained were within normal ranges for each line and hen age. Additionally, other parameters such us morbidity and mortality were not significantly different in those lots in which the hens consumed diets with intermediate levels of cassava flour.

Table 15. Diets for layers without and with 10% inclusion of cassava root flour.

Ingredients %	Check	Cassava flour 10%
Maize	57.80	45.30
Cassava flour		10.00
Soybean meal	16.20	15.00
Toasted integral soybean	5.30	9.10
Fish meal (65% protein)	5.00	5.00
Wheat bran	3.50	3.50
Calcium carbonate	9.71	9.64
Calcium phosphate	0.95	0.91
Salt	0.30	0.30
Liquid methionine (88%)	0.18	0.20
Vitamins and minerals	0.10	0.10
Additives and pigments	0.50	0.50
	Nutritional composition	
Metabolizable energy, Mcal/kg	2.75	2.75
Protein, %	17.50	17.50
Lysine, %	0.91	0.91
Methionine, %	0.44	0.44
Methionine + Cystine, %	0.75	0.75
Linoleic acid, %	1.36	1.39
Calcium, %	3.90	3.90
Available phosphorus , %	0.45	0.45

Table 16. Performance of layers without and with 10% inclusion of cassava root flour in the diet. Weeks 48 to 55.

	Check	Cassava flour 10%
Consumption, g/hen/day	102.6	103.2
Egg laying, %	89.2	89.5
Feed conversion per dozen of eggs	1.4	1.4

Source: *Gutierrez and Martinez, 1998.*

Table 17. Diets for white and red layers without and with 10% or 20% inclusion of cassava root flour.

Ingredients, %	Check	Cassava root flour 10%	Cassava root flour 20%
Maize	41.10	34.10	23.00
Cassava flour		10.00	20.00
Soybean meal	8.10	10.40	11.80
Extruded soybeans	20.00	20.00	20.00
Rice polishings	10.00	10.00	10.00
Wheat bran	9.10	4.30	3.60
Calcium carbonate	9.60	9.50	9.40
Calcinated bone flour	1.30	1.40	1.40
Salt	0.35	0.35	0.35
Dl-methionine	0.18	0.19	0.21
Vitamins and minerals	0.20	0.20	0.20
Additives and pigments	0.10	0.10	0.10
Nutritional composition			
Metabolizable energy, Mcal/kg	2.70	2.70	2.70
Protein, %	17.00	17.00	17.00
Lysine , %	0.85	0.85	0.85
Methionine, %	0.45	0.45	0.45
Methionine + Cystine, %	0.70	0.70	0.70
Linoleic acid, %	1.74	1.49	1.37
Calcium, %	3.90	3.90	3.90
Available phosphorus, %	0.42	0.42	0.42

Table 18. Performance of Red Layers (Lohmann Brown) without and with 10% or 20% inclusion of cassava root flour in the diet. Weeks 78 to 88.

	Check	Cassava root flour 10%	Cassava root flour 20%
Number of layers	3,840	10,956	5,160
Consumption, g/hen/day	115.10	115.80	114.80
Egg laying, %	69.30	65.70	65.10
Feed conversion per dozen eggs	2.00	2.12	2.11

Source: *Buitrago and Lucket, 1999.*

CONCLUSIONS

In many tropical regions, cassava appears to be a profitable energetic alternative to partially or totally replace cereal grains used in poultry feeding programs. The calories obtained per unit of cultivated area is usually greater for cassava as compared to cereals.

The integration of cassava with poultry production programs demands special efficiency and industrialization schemes to guarantee the cassava volumes demanded by the poultry sector, at competitive prices and with the quality standards required.

The use of high-yielding varieties, the mechanization of planting and harvesting, the industrial process of transforming the roots into flour, are some *sine qua non* requirements for the establishment of an efficient, viable integration between the cassava and poultry sectors. There have been recent advances in all of these components that are contributing to reduce production costs and increase the competitiveness of the crop.

Due to the protein deficiency of the cassava root, the price of the cassava root flour needs to be 25 to 30% lower than the price of cereals (sorghum, maize), to be able to enter in the poultry feeding programs.

In broilers and layers feeding, cassava root flour and cassava foliage flour are excellent sources of energy, protein and natural pigments.

Cassava foliage flour must not be included in diets for broilers or layers at levels higher than 5-6% due to its high fiber content and low energy level.

Cassava root flour has important limitations in the protein and fatty acid content. This is a reason why the balance of the final diet requires an effective complementation of these two nutrients. In numerous experiments it has been demonstrated that integral soybean is an excellent supplement to compensate for the nutritional deficiencies of cassava root flour.

As long as the broiler diet is pelletized, cassava flour can be used to totally replace the cereal grains in the diet, without affecting the performance. For diets in the form of flour, it is not recommended to include more than 25% of cassava root flour due to its dusty nature, which causes difficulties in consumption.

In the case of diets presented in the form of flour, it is recommended to replace cereals by cassava root flour up to 50%, which is approximately equivalent to using 25% of cassava root flour in the diet.

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