Poultry feeding: fifty years of research at the Institute of Animal Science

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This paper is aimed at reviewing the information obtained from studies carried out at the Institute of Animal Science related to poultry feeding in the period 1965-2014. Aspects concerning the utilization of products and by-products of sugar cane, by-products of the sugar industry, cassava products and by-products, energetic and protein sources, minerals as well as additives are considered. Advances attained in import substitutions are reported.

Key words: *poultry, feeding, agroindustrial products and by-products*

INTRODUCTION

The launching of the first number of Cuban Journal of Agricultural Science in 1967 allowed the possibility of giving information of the work of researchers on poultry subjects. During almost 50 years, through this publication the main results obtained at the Institute of Animal Science (ICA) have been passed on to the scientific community and to different Cuban and foreign institutions.

First experiments made at the Institute of Animal Science were directed to use sugar cane as main raw matter for the preparation of feeding products for the different species.

Scientific papers published on this topic are, in their majority, directed to the search for new feeds and to poultry management in the different productive systems. Also they dealt with aspects related to the utilization of additives for improving feed values, animal performance and the economic efficiency. All this with the purpose of producing non-conventional feeds that substitute imported sources and make cheaper the production costs in Cuba and in tropical countries with similar productive conditions.

STUDIES WITH PRODUCTS AND BY-PRODUCTS OF SUGAR CANE

For sugar cane producing tropical countries, it is of great interest the substitution of raw matters in the diets that, regularly, are imported, by sugar cane by-products. From the sugar cane crop products and by-products are obtained that can be used efficiently in poultry feeding. Among these high-test molasses, final molasses, raw sugar, filter cake mud oil, saccharina, saccharomyces yeast and torula yeast growing on molasses or vinasse.

High-test molasses is a product with great sugar contents contributing high ME to the formulation. With it, the energy contributed by the maize in the diet can be partially or totally substituted. First studies carried out by Pérez *et al.* (1968) in broilers implemented maize substitution in the diet by 44 %. Pérez and Preston (1970) demonstrated that this source attains to substitute 100 % of the energy contributed by the cereal, with excellent results in the growth and viability of this category.

Years later, Valdivié *et al.* (2004ab) introduced a new feeding system with *ad libitum* inverted high-test molasses and a restricted protein-lipid-vitamin concentrate. These authors indicated that the high-test-soybean meal system can be applied in poultry feeding from 18 d of age and even from one day old. However, Hidalgo *et al.* (2005) reported that the high-test soybean meal system allows adequate yields of edible portions, but as main inconvenient refer that this adheres to the plumage and its high sugar content attract the flies.

For layers, papers of Pérez (1968) were published in which up to 24 % maize were substituted by a high-test molasses-final molasses combination. Better feed conversion, greater number of marketable eggs and less broken eggs were obtained in the studied system.

Similar results were attained on working with other poultry species (ducks, turkeys and geese). However, Valarezo and Pérez (1972) demonstrated the tendency toward the increase of pendulous crop with the highest inclusion levels in turkeys.

Final molasses of sugar cane, from its composition to its use in feeding was studied by different research workers. Álvarez and Ly (1975) demonstrated that

is has a laxative effect that augments feces humidity, when more than 16 % is included in the rations. Also, it increases the speed of transit of the feed throughout the gastrointestinal tract and decreases dry matter and nitrogen retention.

According to Valdivié (1977) final molasses increases the fermentative processes in the crops and caeca as the inclusion percentage in the diet is increased. Likewise, these authors verified alterations in the liver and pancreas of the birds, related to the high content of minerals (Marrero 1977). Valdivié (1977) indicated that with the adaptation of the birds to the final molasses an adequate nutritional performance is obtained and the digestive disorders decrease.

In laying hens, González and Ibáñez (1973) demonstrated that with up to 30 % of the final molasses in the rations, adequate productive results are attained. These authors concluded that during the first production months, layers with final molasses produce less that the controls but at the end of laying the inverse occurs and the annual production of layers is balanced.

Raw sugar. Raw sugar contains between 96 and 99 % of sucrose, therefore it is an excellent source of metabolizable energy for birds. However it lacks amino acids, lipids and vitamins, thus, on substituting cereals in the diet, this must be adequately balanced.

When high levels of this source are employed it is recommended the use of yeast in the diet for guaranteeing the contribution of the B complex vitamins. Similarly, lipid supplementation is proposed for covering the essential fatty acid requirements.

Pérez (1971) working with broilers demonstrated that up to 40 % of raw sugar can be included in the diet. This author also obtained a favorable response to the supplementation with 3 or 5 % fat. Similar results reported for the supplementation with vitamins and minerals.

In replacement birds it was attained the total substitution of cereals of the diet, without affecting live weight gain, age at the start of laying and egg weight. According to Valdivié and González (1977), the inconvenient are related to the increase of feed conversion and the dirtiness in the birds' plumage.

Pérez (1971) on assessing this product in layers showed that in rations with high content of raw sugar greater content of methionine are required for attaining the adequate results in production and quality of the eggs. Years later, González *et al.* (1975) evaluated high substitution level of maize by raw sugar (50 %) in layers and demonstrated that on supplementing with B complex vitamins similar results in the productive and quality indicators are obtained.

Filter-cake mud oil. This oil has been included in rations for broilers at levels of 6 and 8 % (Bacallao *et al.* 1976). Its energetic value is similar to that of sunflower seed oil and does not affect poultry performance. As effect of its inclusion in the diet for layers, Rodríguez and González (1977) stated that its incorporation at 10 % does not affect the number of eggs, feed consumption and conversion, but has a bleaching effect on the yolk, due to the absence of carotenoid pigments.

Saccharina. During the eighties at the Institute of Animal Science a technology of protein enrichment of sugar cane was developed through solid state aerobic fermentation. According to Elías *et al.* (1990), this process allowed obtaining an important protein-energy feed for animal feeding.

First results were published by Valdivié *et al.* (1990a) who used Saccharina as maize replacer in the goose diet. The authors showed that this substitution must be done gradually with the respective adaptation of the birds, increasing at the different rearing stages, from 30 to 60 %, without affecting live weight and obtaining greater feather production.

In the case of broilers, Valdivié *et al.* (1990b) attained the inclusion of only 10 %, since higher levels increase crude fiber content and reduce ME content of the diets, affecting in this way the productive performance (Laredo and Valdivié 1990).

González *et al.* (1993a) studied the use of industrial saccharina in the diets for fattening turkeys and they indicated that in the starting stage (21 to 45 d of age) with 15 % of saccharina feed conversion is affected. However, in the finishing stage (46 to 90 d) it was feasible to include 30 %.

In duck diets, the utilization levels are higher than for broilers. In these animals it is feasible to use 10 and 20 % at the initial and growth periods, respectively (Fraga *et al.* 1994a).

The combination of saccharina with other feeds allowed increasing its nutritional value and, in this way, providing more balanced feeds. Fraga *et al.* (1993) suggested the use of 10 % leucosaccharina in broiler feeding. Valdivié *et al.* (1996a) evaluated the use of brown saccharina and sacchaboniato for broilers and suggested their use up to 10 % as substitute of the classical saccharina. They also defined that the maximum inclusion level of the sacchasoyamaize in the feeds for broilers was 20 %. This level allowed obtaining the standard live weight of the birds, the best traditional feed conversion and the reduction by 6 % of the feeding costs of one ton of carcass + edible viscera.

Valdivié and Elías (2006), with the inclusion of 20 % sacchacanavalia in the diet for broilers, evidenced the possibility of reducing the adverse effects of the antinutritional substances of the canavalia grains by submitting them to a solid state fermentation process, since the utilization of feeds was not altered.

RICE BY PRODUCTS

Approximately 563 millions tons of paddy rice/year with high yield is harvested in the world. Since the seventies, the possibilities of using rice and its industrial by-products in poultry feeds, as well as the alternative of feeding birds under grazing conditions in rice areas (Sanz 1975, 1977, 1985) were emphasized.

Among rice products and by-products, paddy rice, rice heads, rice polishing and rice husks have been studied (Valdivié *et al.* 2012).

Rice heads is a by-product of high nutritive value. It is capable of substituting up to 100 % of the cereals in the rations for broilers (Sanz 1975). According to the criteria of Valdivié (1977), this by-product can be utilized in replacement birds and layers with adequate productive results.

The use of rice polishing in poultry feeding is based on its high fiber content (7 and 11 %) and fat, besides its protein contribution (14.7 %). Sanz (1977) on studying the rice polishing fat demonstrated that this is very oxidative, provoking the impossibility of long storage periods.

Studies carried out by Sanz (1977) were aimed at evaluating the optimum substitution level of maize in the diet by rice polishing in broilers. From the results obtained, it was concluded that this by-product when supplied in fresh way can substitute 50 % of the cereals in the rations. The author recommended pelletization of the powder, since this provokes an increase in feed consumption, eliminates the powdery consistency of the rations, increases live weight and improves conversion.

In replacement layers, maize was totally substituted by rice polishing from seven weeks of age until 22. On employing this by-product as only energy source in the diet it was demonstrated that body composition or egg production in the laying stage were not affected (Sanz and Ngo Thy Ly 1976). In the case of layers, Sanz and Gutiérrez (1976) substituted from 50 to 75 % of the cereals, without affecting significantly the productive performance of the birds. As advantages, these authors indicated that the economic feasibility of the exploitation was improved.

CASSAVA PRODUCTS AND BY-PRODUCTS

Cassava is a plant of the tropical zone, cultured in millions of hectares in the world. According to Valdivié *et al.* (2012), 196 millions of tons of cassava root are annually generated from which 52 % are used for human consumption, 28 % for animal consumption and 18 % for industrial processes.

Cassava root is an energy source, rich in carbohydrates and, in particular, starch. From the cassava plant, meals with its roots are produced with and without peels; also leaf meal.

Cassava root contains a glucoside that on activating enzymatically release prussic acid, a harmful substance for the animals. Thus, Montilla *et al.* (1973) recommended inclusion limits in the diet for broilers from 10 until 30 %, respectively.

Layers tolerate only up to 20 % of cassava meal in their rations as maize replacer. When high percentages are utilized in poultry rations, the amino acid balance of the diets, especially the sulfureous must be taken into account.

Valdivié *et al.* (2008) and Zacarías *et al.* (2012a) developed a working methodology with the cassava root, in which they proposed the total substitution of the maize meal in the diet of broilers and up to 53 % in layers. These authors demonstrated that the indicators of performance, live weight, feed consumption, feed conversion and carcass yield as well as meat palatability (aroma, taste and texture) are not affected. As advantage they also reported its positive economical effect, although among their limitations were indicated depigmentation of skin, legs, beaks and abdominal fat of the broilers.

In layers, the above mentioned authors found similar results in egg production. Egg percentage reported was higher than 90 % throughout the whole experimentation. Also stood out greater egg weight of the birds consuming cassava root meal and as inconvenient they only pointed out less yolk coloration, due to low carotenoid content in the diet.

For replacing birds, these same authors demonstrated the possibility of substituting 50 % of maize by cassava root meal of first quality (74 % starch) from birth until 17 weeks of age, without altering the productive performance.

In the case of cassava leaf meal, some authors question its nutritive value for animal feeding However, Montilla *et al.* (1977) working with foliage meal with 19.7 % protein and 27.7 % fiber in pelletized diets for broilers obtained similar productive results with improvement of the economical indicators. Zacaría *et al.* (2012b) used this meal as pigment. These authors demonstrated that the inclusion of 2 % of this product in the diet of broilers and replacement layers allow pigmentation of beak, legs and meats. In the case of layers, for maintaining pigmentation of 6 in Roche's scale, diets must be supplemented with 2.5 % cassava foliage meal, generating also positive economical effect.

OTHER ENERGY SOURCES

Another of the alternative sources evaluated was the breadfruit meal (*Artocarpus communis* Forst or *Artocarpus incisa* or *Artocarpus altilis*). Valdivié and Alvarez (2003) used this meal as partial substitute of the maize meal in broiler diets and recommended the inclusion of 20 %, with productive results similar to those of the maize-soybean diet. In another study, Leyva *et al.* (2010) indicated that the maximum inclusion limit of breadfruit meals is 20 %, since with 30 % live weight, feed consumption and feed conversion worsen.

Also, the utilization of fats and oils for decreasing the percentage of inclusion of the traditional energy sources in the diet has been studied. On this subject, Lon Wo and Rodríguez (1983) used non-acidulated sunflower soapstock in broilers, with the inclusion of up to 15 % between three and eight weeks of age. On the other hand, Fraga and Valdivié (1985) utilized the sediment of crude sunflower oil in the finishing diets of chickens. In the above mentioned studies the same conclusion was reached: the inclusion of these by-products allows improving the texture of the diet and makes feasible excellent results in poultry performance.

Lon Wo and Rodríguez (1986) carried out a comparison between different alternative energy sources for broilers: tallow, acidulated (ASOS) and non-acidulated (NASOS) sunflower oil soapstock, rancid lard and filter-cake mud oil. As results they obtained that, according to the productive performance of the birds, best by-products were ASOS, tallow and NASOS. However, they mentioned that the use of any of these energy sources improve the productive performance of the broilers.

PROTEIN SOURCES

In Cuba unicellular proteins have been studied for poultry production from by-products of alcohol production. Among them can be cited Saccharomyces yeast and torula yeast growing on molasses, marrow and vinasse. Torula yeast is one of the alternative protein sources of highest potentiality in sugar cane producing countries.

Yeasts constitute a protein source rich in vitamins of the B complex. Also, they have high lysin content which is highly available for the birds. Valdivié (1976) mentioned that the torula yeast produced in Cuba is poor in methionine and, according to the performance results of the broilers the supplementation with DL-methionine is necessary; not so for layers and its replacers.

One of the main restrictions of yeasts is related to the palatability and the content of nucleic acids. These characteristics can vary with the yeast species. In general, yeasts have a bitter flavor and, when employed at high levels in the diets, can decrease the palatability, mainly because of its powdery condition and sticky consistency that interfere on animal consumption. Also an increase in feces humidity can be provoked.

In layer, Pérez *et al.* (1969) utilized torula yeast or saccharomyces as substitute of soybean meal and demonstrated that adequate results are attained. Valdivié and Compte (1976) assessed this protein source in replacement birds and evidenced that during the starter rearing stage (0 to 6 weeks of age) 20 % torula yeast can be included and that from 7 to 22 weeks of age 100 % can be substituted. In layers fed rations with 18 % torula yeast, the productive performance or the egg quality were not affected.

Valdivié (1975) evaluated dried torula yest in broilers attaining the inclusion of up to 38 % in the diet. However, birds fed with diets of 30 and 38 % showed humid and sticky feces. Thus, the above mentioned author suggested the inclusion of up to 20 % of torula yeast in feeds for broilers of a medium growth potential for attaining adequate productive results.

In studies carried out by Pérez *et al.* (1969) it was demonstrated that the optimum inclusion level was close to 15 % in layers, without affecting egg production. For broilers, Gutiérrez (1974) stated that for Cuban conditions the protein level in diets based on sugar was approximately 19 % of the DM. She added that it is advisable the supplementation of diets with 0.1 % of methionine.

Rodríguez *et al.* (2014) worked with torula yeast grown on vinasse in the diet for replacement layers. They concluded that 20 % can be included of this protein source in the starter and growth diet without affecting the performance of birds.

Fraga *et al.* (1992 and 1994b) assessed the possibility of introducing forage of the aerial part of some plants as *Leucaena leucocephala*, *Chenopodium quinua* W. and *Amaranthus cruentus* in the feeding of broilers. The recommended levels for broilers were low (5 %) and up to 10 % for layers.

In the study of Cino *et al.* (1999) are evidenced the economical possibilities of different legume species, soybean (*Glycine max*.) dolico (*Lablab purpureus*), mucuna (*Stizolobium aterrimum*), canavalia (*Canavalia ensiformis*, L.), winged bean (*Psofocarpus tetrazonalabus*) and vigna (*Vigna unguiculata*), as alternatives for substituting partially the protein sources used in poultry feeds

Lon Wo *et al.* (1998) demonstrated that *Vigna unguiculata* among the evaluated legumes is the most promissory alternative protein source for broiler feeding due to lower presence of antinutritional factors. These authors on substituting 35 % of the imported soybean cake meal by sun-dried vigna meals in iso-energetic

but not iso-protein wheat diets, found economic benefit through the partial substitution of the imported protein source, decrease of the dietetic protein and absence of synthetic amino acid supplementation.

In another study, Lon Wo and Cino (2000) recommended the substitution of up to 50 % of soybean cake meal by raw vigna grain meal without affecting the productive performance of broilers, even with economical advantages until the level of 75 %. They also demonstrated that the addition of amino acids higher than that use in a conventional maize-soybean was not necessary. Later, Lon Wo *et al.* (2001) attained the substitution of up to 60 % of the traditional protein source by the alternative and 16 % of the cereal with the maximum inclusion level (20 %),

On evaluating the processes of extrusion, toasting or sun-drying of raw grains of mucuna (*Stizolobium aterrimum*) and canavalia (*Canavalia ensiformis*), Lon Wo *et al.* (20002a) corroborated the need of treating the legumes due to the presence of antinutritional factors. These authors reported improvement in the nutritional quality of the meals and in the productive performance of the broilers.

MINERALS AND ADDITIVES IN POULTRY DIETS

Mineral availability in the country made possible the evaluation of some of them for its use in poultry feeding and, in this way, contributing to the substitution of imports.

Berríos *et al.* (1983) included different levels (0, 2.5, 5 and 10 %) zeolite in the diet for layers. They obtained similar results regarding egg production and feed consumption. However, these authors found that feed conversion was favored significantly for all the levels of zeolite studied. Also, they reported a reduction in the costs of the diet due to the inclusion of this mineral.

Lon Wo and González (1991) confirmed the positive results attained with the use of 5 % zeolite. These authors also demonstrated the potentialities of bentonite and kaolin. Taking into account the adsorbent capacity of zeolites, Lon Wo *et al.* (1993) verified that Cuban zeolites offer valuable contribution to poultry production, by increasing the productive efficiency, improving the metabolic status and guaranteeing the hygienic quality of the feeds and poultry health, acting as decontaminator and detoxicant.

Lon Wo and Cárdenas (1995) developed three experimental works for evaluating different zeolite deposits. These authors concluded that it was feasible the use of any of the evaluated deposits, regardless the type of cereal, except that of La Pita. Also they demonstrated that there could be differences in the productive performance due to the effect of the predominating type of zeolite, the possible intercalations present, the level of extraction and processing among other technological factors.

Lon Wo and Cárdenas (1996) designed a feeding strategic with the use of zeolite in substitution of total feed for laying hens. This technique allowed controlling food intake. This way it was confirmed that zeolite have beneficial effects on the efficient utilization of foods

On considering the potentialities of the zeolites, Acosta *et al.* (2005) employed them for guaranteeing feeding schemes that will attain protein saving and amino acid supplementation that will contribute to attain greater nutritive efficiency and lower environmental pollution. These authors found favorable interaction regarding the use of zeolite and the feeding schemes. Thus, they suggested that the introduction of changes in starter diets of broilers at 21 d, with the use of zeolite, can give rise to greater yield of meat A and leaner carcass.

In layers, Lon Wo *et al.* (2010) demonstrated that it is possible the feeding manipulation with the inclusion of natural zeolites and contribute to decreasing environmental pollution and concentration of bad smells.

Acosta *et al.* (2009a) evaluated the phosphorite of the deposit Trinidad de Guedes (FTG) as phosphorus source for its inclusion in the diet of boilers and layers. These authors determined through growth and bone mineralization trials that the relative biological availability of phosphorus in this product is high and very similar to that of dicalcium phosphate of high quality, thus it can be considered a good source of phosphorus for the birds.

Acosta *et al.* (2009b) demonstrated through the productive performance and the mineral metabolism of layers that it is feasible the total substitution of the imported phosphorus source by FTG. These authors indicated that the available phosphorus can be decreased, recommended for phase 1 of laying (0.40 %), until 0.25 %, without altering the productive indicators (Acosta *et al.* 2009c).

ENZYMES

The utilization of enzymes in poultry feeding not only represents an improvement in the nutritional value of the feeds, but it also allows increasing their possibilities in the use of raw matters. Likewise, they offer greater variability of feeds and more gains to the producer of balanced feeds for improving the utilization of different protein sources eliminating the antinutritional factors as the oligosaccharides of the legumes (Acosta *et al.* 2006).

In a study carried out by Lon Wo *et al.* (2000) for assessing the use of β mananasa in maize-soybean diets for broilers, the potentialities of this enzyme was demonstrated for increasing nutrient digestibility and, thus, their efficiency of utilization.

From all the phosphorus present in grain and oleaginous plants, only from 10 to 30 % is found

available for birds. Therefore, Acosta *et al.* (2006) stated the need of supplementing with this phytase enzyme in layers with low level of available phosphorus, since not making use of it mineral metabolism alterations will be manifested and in the productive performance. In broilers, Acosta *et al.* (2007a) reported that the use of phytases in diets of low contribution of available P (0.24 %) can optimize the dietetic phosphorus, guaranteeing the productive performance and adequate mineral homeostasis.

In another study, Acosta *et al.* (2008a) indicated the need of supplementing, at least, 250 mg/bird/d of phosphorus through an inorganic source or with the utilization of 450 U/kg of phytase. In the same way, they suggested that the contribution of available phosphorus (Pa) can be decreased to 0.14 %, or not using inorganic phosphorus source when the Natuphos phytase enzyme is included, since this guarantees an additional phosphorus availability that covers parts of the dietetic requirements necessary for an optimal performance and mineral homeostasis.

Another of the products necessary for the adequate formulation in poultry diet is calcium carbonate. But, in the same way, studies have been realized for attaining its substitution by other products of lower cost. Delgado *et al.* (1988) evaluated the substitution of calcium carbonate by sea shells in the broiler diet. The authors demonstrated that shells can substitute in full the calcium in the diet.

Among the animal growth promoters are the probiotics, fitobiotics and prebiotics, arising as alternative to the antibiotics. As known these latter have generated problems of microbial resistance or of residual effect in the meats. In this sense, Acosta *et al.* (2007b) demonstrated the possibility of increasing the economical and biological efficiency of broilers with the use of a probiotic mixture (*Lactobacillus acidophilus* and *Lactobacillus rhamnosus*).

Acosta *et al.* (2008b) recommended to use a multistrain probiotic with a phytobiotic mixture (based on essential oregano, citric and anise oils) and their combinations, as natural promoter of broiler growth, since they influence positively on the performance of these animals and on its health status and on breast yield. Also, these authors suggest that there are aspects as the digestibility and nutrient retention that must be investigated further.

Other additives are employed in poultry diets for improving the quality of the final product according to the demand of consumers. For that, the utilization of pigmenting substances for yolk coloring and of meats was described by Prohaszka (1968). This author compared a synthetic pigmenting substance to *Bixa orellana* (annatto) and obtained a coloring 75 times higher for the synthetic product regarding to annatto in the eggs.

FINAL CONSIDERATIONS

It is evident that the variety of products and by-products that can be found in the tropics, allow covering partially or totally the nutrients required by the birds. Similarly the wide knowledge of researchers in the tropical area allow adjusting each one of the feeding systems to the different rearing types and species studied for attaining in this way the sustainability and support of productions.

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