Pig feeding with nontraditional products: fifty years of research at the Instituto de Ciencia Animal

M. Castro and Mayuly Martínez
Instituto de Ciencia Animal, Apartado Postal 24, San José de las Lajas, Mayabeque, Cuba
Email: mcastro@ica.co.cu

This study reports the main results obtained at the Instituto de Ciencia Animal since its creation up to 2014, on the use of local resources for feeding pigs. It also refers to the advances in the use of sugar cane and its derivates, which are biotechnologically obtained. The study shows its usefulness, effectiveness, and possibility for replacing imported raw matter. This research also refers to biochemical and physiological aspects of pigs.

Keywords: *feeding, pigs, products, agro-industrial by-products*

INTRODUCTION

Most developing countries are located in tropical and subtropical regions, where, paradoxically, there is an incalculable potential for food production. Within this context, it is very important the production of high volumes of biomass in form of sugar cane (*Saccharum officinarum*), which is widely present in these regions.

Cuba was one of the world major sugar producers from sowing sugar cane, which was an excellent providing plant, with average global yields up to 58 t/ha/year and rotational cycles from six to seven years. The main purpose of this grass is been sugar production for human consumption. The great amount of products and by-products, and the low availability of traditional feed for feeding pigs in Cuba were the causes for the study of nutritional possibilities of sugar cane products and by-products, carried out by researchers from Instituto de Ciencia Animal from the Republic of Cuba.

There are different sugar cane derivates with adequate nutritional characteristics for feeding pigs. Sugar cane juice, discarded sugar, different types of molasses, yeasts as protein sources are examples of derivates, as well as different feeds developed through simple biotechnological ways. This allows to potentiate pig feeding, together with an important participation of products obtained in areas handled by pig producers.

Nowadays, moments in which Cuban sugar cane production seeks to increase productive levels and the organizational changes in having lands demand important volumes of food for animal production, the application of results obtained from researches carried out in the Instituto de Ciencia Animal is an excellent achievement before the need of decreasing importations, diminishing costs and guaranteeing an efficient local food security.

This paper refers to the main results obtained from researches carried out in the Instituto de Ciencia Animal since its creation up to 2014, related to the use of products and by-products from sugar industry for feeding pigs.

STUDIES ON DIFFERENT TYPES OF MOLASSES, OBTAINED FROM SUGAR CANE, AND ITS USE FOR FEEDING PIGS

Using sugar cane juice, it is possible to obtain several types of molasses: high-test molasses, which contains every sugar; integral molasses, which is similar to the previous but with impurities; A molasses, which is the result of letting 75 % of all the recoverable sugar; B molasses, with 70 % of recoverable sugar; and C molasses or final molasses, with 58 % of the total, when it is not possible to extract more sucrose with the available technology.

Studies performed at the Instituto de Ciencia Animal, during the period 1966-1968, confirmed the limitations of final molasses. However, high-test molasses, with an apparent digestibility of 92 % for dry matter, did not have problems and was successfully used for replacing cereals in diets for pigs between 20 and 90 kg of liveweight. The same happened with final molasses plus sugar (MacLeod *et al.* 1968), which has a higher sugar content and lower content of minerals and other components of it.

Molasses is produced through the clarification of sugar cane juice, its partial inversion (to avoid sucrose crystallization) and finally its concentration up to 80-85 ºBrix. Clarification, through the addition of calcium hydroxide, precipitates certain impurities (including waxes, gums, carotene, bagasse pith, peptones and other nitrogen components), which are removed by filtration. This insoluble residue is called filter cake mud.

Because the process of clarification represents an additional cost in sugar cane processing (in cattle food

production), it is important to know the food value of molasses prepared without this process. Studies suggested not using integral molasses as the only energy source in diets for growing pigs, but as a partial substitute of it (Velázquez and Preston 1970).

Diéguez and Menchaca (1973), after comparing high-test molasses with maize, did not obtain significant differences in daily liveweight gain, in food conversion or in food intake, although they concluded that caecal fermentation pattern in high-test molasses diet was different to that of maize, with an increase of the volatile fatty acids.

Velázquez and Preston (1973) did not observed significant differences in daily weight gain or in dry matter conversion in high-test molasses diets with levels of crude protein from 10 to 21.6 % of DM. Protein conversion decreased significantly from 0.84 to 0.37.

Ly and Castro (1984) made comparisons with the inclusion of final molasses in similar percentages to those of maize and high-test molasses, in pigs between 60 and 90 kg of liveweight. These authors reported worst daily gains and conversion for final molasses with a reduction of voluntary intake, apparently due to an excessive ingestion of water.

Later, using weaned animals at 21 d old, the possibility of replacing up to 75 % of the feedstuff cereal by high-test molasses was confirmed (Ly and Díaz 1979). This result, demonstrated with different types of molasses and in different categories, with lower protein requirements than those referred by the international standards, is possible because molasses have lower energy density than cereals. This favors the best use of protein at the lowest levels, in which there is a better energy-protein relation and a decrease of the need of using energy for eliminating products from protein metabolisms.

The study of protein supplementation to diets of high-test molasses continued to be analyzed by the researchers from the institute. Lezcano and Elías (1975) and Lezcano (1976) showed the possibility of substituting 100 % of the traditional protein sources of the diets by torula or saccharomyces yeasts, without differences in animal performance and carcass composition.

Final molasses has been the most studied in Cuba due to its economical advantages as a byproduct from sugar production. Therefore, there is more experience in its productive use than in other molasses.

Castro (1976) and Marrero and Díaz (1976) pointed out that pigs could reach daily gains of 500 g, apart from the physiological diarrhea, after including levels of final molasses between 65 and 73 % of DM in the diet.

Díaz (1977) confirmed these results in developing females. This author also demonstrated the possibility of using crude protein levels of 235 g/d, and obtaining females with a good body development and optimal ovulation rate.

The use of additives for more efficient diets of final molasses has been widely developed with fiber sources (Savón 1984 and Díaz *et al.* 1985), copper sulfate (Castro *et al.* 1985), zeolite, selenium and vitamin E (Castro 1976). In some cases, remarkable increases in animal performance have been achieved.

Final molasses has been mostly used for feeding pregnant sows, since Velázquez *et al.* (1978) did not found differences in the reproductive performance between sows fed with cereal diets or those fed with diets based on final molasses (67 % in HB).

Other researchers (Díaz 1977) used final molasses as the only energy source and obtained a good reproductive performance, but low weight gains (total and net) during gestation and, consequently, a very low negative balance in weight. These conditions, after several reproductive cycles, could limit productivity and usage time of reproducers.

There were also interesting aspects in the use of the feeding system, like low weight of kids at birth and impossibility of increasing gestational weight gain with the increase of final molasses intake.

The significant linear relation ($P < 0.001$) established between total weight gain and gain of the first 60 d of gestation demonstrates that weight gain of the first two months of pregnancy represents 58 % of the total gain ($Y = 0.19 + 0.59 x$). Considering that, during this period, there is more gestation anabolism and sows accumulate more reserves to be mobilized during lactation, it is understandable the low weight of the animals at the end of this stage, because, generally, they lose more weight than that accumulated during gestation, as Velázquez and Díaz (1987) demonstrated. This indeed is conditioned by the low energy density of this product.

Studies carried out with different protein levels (Díaz 1977) confirmed those obtained with traditional diets, because the reproductive performance did not vary when the intake of crude protein decreased (from 280 to 130 g), although weight gains during gestation stayed low.

RESEARCHES ON BIOCHEMISTRY AND PHYSIOLOGY

Regarding biochemistry and physiology of nutrition, different aspects related to molasses as the only source of carbohydrates have been researched by several Cuban authors. The first studies were related to digestive characteristics of diets of high-test molasses (Ly 1971) or final molasses (Savón 1984), or these same diets mixed with torula yeast, as the only protein source (Carrillo 1971 and Boucourt 1982). Among the most relevant results, generally, sugar cane molasses determines high indexes of diet DM digestibility, when pigs are fed with

diets as main source of carbohydrates.

Only after comparing the different molasses among them, it is possible to confirm that when they have more amounts of carbohydrates, they are more digestible. On the other hand, unlike final molasses, other sugar cane molasses, like high-test molasses, in which sugar extraction has not been exhausted, do not determine a laxative effect, neither in weaned animals nor in growing and fattening stages. With that, there is an evident improvement of performance traits of economical interests (MacLeod *et al.* 1968 and Ly and Castro 1984).

It has been confirmed that the decrease of fecal DM in pigs consuming final molasses as the main energy source is closely related to the decrease of digesta retention time (Marrero and Ly 1977b and Ly 1984), mainly in the large intestine (Ly 1985). The causes of this phenomenon have been explained in different moments.

The annulment of diarrhea, due to diluting final molasses with crude sugar, led to the initial hypothesis, which stated that, this way, the potassium content of final molasses obviously decreased, and diarrheas produced by high levels of final molasses were caused by a the excretion of great amount of potassium ions (Preston and Willis 1969). Later, this hypothesis evolved with the inclusion of magnesium as a diarrhea causing agent (Savón 1984). However, the substitution of final molasses by sugar dilutes the mineral fraction and enriches the diet with very digestible sugars.

Another way of focusing the effect of final molasses could be deduced by the results of Velázquez y Preston (1970), who compared the response of pigs fed *ad libitum* with high-test molasses or integral molasses. Velázquez and Preston (1970) found that excretes were drier with high-test molasses (DM 41 %) than with integral molasses (DM 22 %). Likewise, these authors stated that performance traits improved evidently with high-test molasses. As it is known, the difference between these two types of molasses is that integral molasses is a high-test molasses without clarification. This means that this molasses has not underwent a process of impurity extraction. It should be assumed that, even with clarification, these impurities are not totally removed, and, during the subsequent sugar separation, they will gradually concentrate so they can constitute, at least, 25 % of the final molasses in dry basis, which means more than the double of mineral concentration in this type of molasses.

The initial hypothesis of Velázquez and Preston (1970) about the cause of the excessive humidity of excretions of pig fed with integral molasses is impurities that normally are removed with filter cake mud, is perfectly compatible with every type of molasses, from high-test up to final molasses, which represent molasses with a minimum or maximum level of impurities.

This has also been demonstrated through the dilution of final molasses with high-test molasses (Marrero and Ly 1977a). All these evidences, although there is no complete theoretical response to the problem of laxative effect of final molasses, have opened biologically viable options, which do not reduce the energy density of diets, as in the case of less digestible materials, like different fiber sources (Lassota 1969 and Rodríguez *et al.* 1988).

The use of large proportions of sugar cane molasses in pig feeding means the substitution of starch by sucrose, as the main diet carbohydrate. This determines, more than changes in digestion, a dietary modification in the metabolic profile. This can be explained because of the existing differences in the energy density of amylose or amylopeptin and sucrose disappear during the digestive process. However, it seems that pig intestinal wall is unable to turn quantitatively fructose into glucose and, the first of these hexoses gets into the organism as such (Ly 1974) or at the same time, as lactic acid (Bjorkman *et al.* 1934).

Therefore, it should be expected that hepatic metabolism performs a preponderant work in synthesizing glucose. This fact is probably related to the decrease of efficiency of fructose metabolizable energy in other non-ruminant species and, probably, on pigs. It is possible that these circumstances may contribute to establish a disadvantageous difference for sucrose, regarding starch at energy level.

Some indicators of metabolic misuse of fructose waste could also be urinary losses of fructose, from 3 to 5 % of the consumed, and not of glucose (Ly and Velazquez 1970), despite the first of these two are always present in lower blood concentrations than glucose (Ly 1974).

The possibility of a compensated metabolic acidosis state has been demonstrated in pigs fed with final molasses or still in mixtures of sucrose, glucose and fructose as carbohydrate sources, regarding results of Savón *et al.* (1987). The decrease of blood pH maybe is not caused by electrolytic composition of final molasses, but by the production of lactic acid from fructose under postprandial conditions. In this sense, final molasses do not influence on the serum profile of electrolytes (Savón *et al.* 1989). This type of changes have created, under other conditions, a decrease of voluntary food intake and osseous disorder, which have not been studied in systems of pig feeding with molasses diets. Actually, it is evident that intake pattern of molasses diets is particularly characteristic in pigs (Ly and Castro 1984).

Marrero and Ly (1976) data could illustrate the peculiarities of *ad libitum* fattening of pigs fed with molasses diets. The voluntary food intake can decrease evidently during the last stage of this fattening, regarding the first one. These characteristics of molasses are very disadvantageous in fattening pigs because the increase of voluntary intake over the normal levels could compensate the lowest energy density of molasses diets, regarding those of cereals and grains.

Díaz *et al.* (1989) demonstrated that it was possible to use also B molasses in lactating sows because there were no differences among treatments in the performance of

sows and their litters, after a total substitution of cereal sources in the diets of these animals.

Since its creation, the Instituto de Ciencia Animal has dedicated several years to the study of sugar cane molasses for pig feeding, as well as other Cuban institutes. These researches bring a great amount of information on nutritional, physiological and management characteristics of this food, which has not been traditionally used in high feeding levels of this species. This knowledge makes possible for countries currently producers of sugar cane, as in the case of Cuba, to develop their production plans with an intensive use of these products as the main energy source, mixed with torula yeast cream (produced from distillery vinasse) in order to created a food rich in energy and protein.

Economical aspects derived from cereal prices, which condition the need of producing meat with non conventional diets in tropical countries, support the importance of the studies developed with these feeding systems in Cuba. Although, for years, sugar-enriched molasses were not taken into account in researches on pig feeding, recently, thisfield of work has been retaken, from B molasses for growing fattening pigs and pregnant sows due to the its economical advantages in the current context, regarding sugar prices. With this alternative, good quality sugar for human consumption is also produced, as well as highly nutritional molasses, compared to maize, when it is used in pig feeding.

STUDIES ON SUGAR CANE STEM

The use of sugar cane, ground and dehydrated until acquiring a meal condition, has been a tested option and offers perspectives of usage in pig feeding.

Lamazares *et al.* (1988) studied the partial substitution of cereals for sugar cane meal in piglets, from their weaning (33 d old) to 68 d. These authors found no significant differences in the performance of the animals for the studied treatments (0, 10, 20 or 30 % of sugar cane meal), with a minimum of mortality during the trial, and a similar food intake at all studied inclusion levels. The possibility of turning sugar cane into meal favors its storage and allows a more rational use of it, because it is offered to pigs as feedstuff.

The pattern of intake, macro and micro-morphometric indicators of the gastrointestinal tract and some digestive measuring were studied in pigs that consumed, for five weeks since weaning, 20 and 40 % of dehydrated sugar cane (8 and 12 % of CF, 19 and 28 % de NDF) as a substitute for cereals. Frequency, time and speed of ingestion, as well as the intake during the first hour after its supply, do not differed between the control and 20 % of sugar cane, and decreased for 40 % (Rodríguez *et al.* 1991).

Morphometry studies showed a higher contribution of the stomach and a lower one of the large intestine with the inclusion of sugar cane meal. In the stomach, there are inferior values for weight increase and mucus volume, indicators of a positive effect of the treatment on weight and area, and of a higher muscle volume with 40 %. All this, and other results (Rodríguez *et al.* 1988), indicate that the effect is related to musculature and, consequently, to mobility and change.

Pre-caecal passage increased with the inclusion of sugar cane. However, there was evidence of higher dry matter retention in the large intestine, with 20 % (Rodríguez *et al.* 1989). Results indicated that 19 % of NDF, from dehydrated sugar cane meal (19 %) in cereal diets, can tolerated and even favorable for weaned pigs.

USE OF SACCHARINA FOR PIGS

Another important product (Saccharina) with economical and nutritional possibilities for pig feeding was developed by solid state fermentation, at the Instituto de Ciencia Animal, during the last decade of 19th century (Elías *et al.* 1990). With this biotechnological process, scarcity of protein in most of the products from sugar cane is corrected, with the obtaining of a product called Saccharina, which can reach protein values compared to cereals. This aspect is very important for tropical areas.

Even though this result has a great economical and productive importance for food security of the country, it has not been considered as strength for increasing pig production (and other species) with a natural resource, which is widely represented and abundant all over the national geography. This resource could be used for diminishing a part of the dependence on imported food for animal production, which represents a considerable amount of savings for Cuban economy.

The first results demonstrated that the inclusion of up to 20 % of Saccharina for feeding weaned piglet at 33 d old do not changed animal performance (Lezcano *et al.* 1990). For pigs of 61 d old and 13 kg of initial liveweight, it was feasible to include up to 30 % of sugar cane Saccharina on feedstuff, as a substitute of cereals, without finding any difference in daily weight gain or in final liveweight at 96 d old.

Later studies with developing females, fed with imported commercial feedstuff and B molasses, demonstrated that including 40 % of Saccharina as a cereal substitute allowed to reach 92.3 kg of average liveweight, in 110 d of stay, with a daily weight gain of 538 g (Díaz *et al.* 1990).

Later, Díaz *et al.* (1997a) stated the use of 60 % of Saccharina on the supplement of pregnant sows

consuming B molasses, since their first reproductive cycle, although its use during lactation was not still recommended.

Studies designed for pig fattening showed the possibility of using up to 36 % of Saccharina, although the need of improving water supply was evident. Nevertheless, animals reached, as average, 107 kg of final liveweight in 112 d (Castro *et al.* 1990).

Different combinations of Saccharina with other foodstuff have been studied. This other foodstuffs elevate the energy character in order to achieve their best usage. Among the studies carried out, Rodríguez (2004) can be cited because this author performed the solid state fermentation with sweet potato, and considerably improved the nutritional quality of the new Saccharina.

Ly and Castro (1995) concluded that the inclusion of Saccharina on the diet has more influence on the best use of the energy by pig, if the inclusion only reaches 20 % of the food, regarding the best use of dietary nitrogen.

Because the fiber component might have a negative influence on the use of larger concentrations of Saccharina in the different pig categories, two different preparations of this product were considered. The first preparation was scraping sugar cane like it is prepared for juice extraction. The second one is removing sugar cane peal, which is the part that provides more fiber to the product. With this, fiber content decreased significantly, almost 50% of the total content, including lignin, and protein content increased. This represents an important step for using Saccharina in monogastric animals (Díaz *et al.* 1997b).

Researches and results obtained with the use of Saccharina are, after 50 years, essential elements for obtaining more satisfactory productions and in agreement with the economical reality of the country. These productions will contribute effectively to cover food needs of population. This way, sugar cane, its products and by-products will also contribute to the nutritional supply of Cubans.

USE OF OTHER NONTRADITIONAL PRODUCTS

Although the main researches have been focused on usage of products and byproducts from sugar cane industry, there are also studies on other products that have contributed to richen food sources for pigs in different categories.

García and Lezcano (1987) evaluated fleshings as a protein source for growing pigs. These authors determined the digestive utilization coefficient (DUC) of the main nutrients, and nitrogen utilization efficiency (NUE) in pigs fed with four levels of fleshings: 0, 34, 66 and 100 % of substitution of protein supplement. These researchers concluded that it is necessary the supplementation with synthetic amino acids when using this product in growing pigs, due to the unbalance of this essential component for these animals.

Another researched product was Vitafert, which was obtained from aerobic fermentation of a mixture of ground sugar cane, poultry manure, urea and mineral pre-mixture (Elías 1993). Díaz *et al.* (1996) evaluated this product for partial substitution of cereals in pig diets during pre-fattening stage, and recommended the inclusion of up to 20 % of Vitafert with economical advantages, without affecting pig performance.

Lezcano and Castañeda (2000) studied the partial substitution of feedstuff for protein residues from alcohol distilleries (PRD), from the fermentation process that contains *Saccharomyces cerevisiae* yeast, which is part of the substrate where they develop and there are enzymes, peptides, amino acids, vitamins and other products of this process and of the catabolism of microorganisms involved. The evaluated levels were 0, 10 and 20 % during the first five weeks after weaning. These authors did not obtained differences among treatments for liveweight, daily gain and food conversion on dry basis during the period in which they consumed PRD. Therefore, they considered as favorable the substitution of feedstuff for 20 % of this product used for feeding growing pigs. In this category, they also determined energy and nitrogen balance with the same substitution levels and found that N digestibility or energy were not affected negatively with the highest level (20 %), which coincides with the performance results previously obtained (Lezcano and Castañeda 2002).

Lezcano and Achang (2002) tested the PRD during fattening stage (50-90 kg) in diets of feedstuff and B molasses. In this category, these authors used 0, 30 and 60 % of PRD for substituting feedstuff and reached a favorable productive performance with 30 % of substitution during the fattening stage. The use of PRD is considered as a regional alternative for pig feeding in Cuba.

Other studies determined the possibilities of *Vigna unguiculata* cv. INIFAT-93 as a protein source for growing pigs (Castro *et al.* 2002). Researchers reported that the optimal inclusion level was 12.8 %, according to the protein requirements of animals. This allows the substitution of 20 % of soybean meal used in diets for this pig category, with favorable economical and biological indicators for Cuban conditions. These results demonstrate that vignas also represent a pig feeding alternative due to the agronomical advantages of this crop.

Fermented muds were also researched in the institute. Lezcano *et al.* (2004) performed a balance of nutrients, after replacing wheat and soybean by four levels (0, 10, 20 and 30 %) of this product, and measured energy digestibility, nitogen, calcium and phosphorous, as well

as their retention in growing pigs. Later, Lezcano *et al.* (2005) evaluated these levels on productive performance of pigs from this category, and concluded with the possibility of replacing 10 % of wheat and soybean meal by fermented muds, with an improvement of feedstuff conversion in this category. Therefore, muds also represent a feeding source for pigs.

More recently, (Martínez *et al.* 2008) studies with distillers dried grains with solubles (DDGS) of maize from ethanol industry have been carried out. These indistries were mainly located at the United States Corn Belt. This by-product has been evaluated integrally in growing pigs and reproducers. Researches on the first mentioned category covered digestive physiology, health, productive performance and nutrient balance, as well as an economic analysis of used diets. Results evidenced the possibility of including up to 20 % of DDGS with the partial substitution of maize, soybean and dicalcium phosphate, with similar productive performance, regarding the control, a marked reduction of diarrheas and mortality and economical advantages for the production of growing pigs. Later, the effect of these levels was determined in nutrient excretion and the previously mentioned results were confirmed (Martínez *et al.* 2010).

Regarding the DDGS evaluation on reproducers, its inclusion was evaluated in levels of 0, 20, 40 and 60 % in pregnant sows for two reproductive cycles, and in levels of 0, 10, 20 and 30 % in lactating sows. Pregnant sows showed good results with 60 % of inclusion without affecting them and their descendants during lactation. Besides, there was a reduction of diet costs when the by-product was included. Lactating sows showed favorable performance indicators with 30 % of inclusion, and there was also an increase of milk production after three weeks, which favored the weight increase of piglets during that period. In both categories, results are 10 % over those recommended in the literature for DDGS, and represent a viable and economical nutritional alternative because three of the most expensive components of pig diet (soybean, maize and dicalcium phosphate) can be partially substituted (Martínez 2011).

Since 2014, several researches related to alternative protein sources have been retaken due to the increase of soybean meal. Regarding that, Ly and Pok (2014) made a review of results with mulberry (*Morus alba*) between 1993 and 2003. These authors included data from their studies on the use of foliage, with suggestions of 20 and 25 % of inclusion on pig diets. Nowadays, several projects are being developed for optimizing the use of mulberry, which, undoubtedly, represents another viable alternative for feeding this species.

FINAL CONSIDERATIONS

There is a wide range of products and by-products with possibilities of taking part of pig diets. Many other sources have been studied with the collaboration of other institutions and through the development of doctoral and master theses. Their results are part of the knowledge of researches, specialists, and technicians from the Instituto de Ciencia Animal since its creation, 50 years ago. This knowledge is offered to everyone who wishes to know more about these aspects.

REFERENCES

Bjorkman, C., Crump, M. & Phillips, R.W. 1934. Intestinal metabolism of orally administered glucose and fructose in Yucatan miniature swine. J. Nutr. 114:1413

Boucourt, R. 1982. Digestibilidad de la proteína de la levadura torula en cerdos alimentados con dietas de miel final de caña. Tesis Dr. C. Instituto de Ciencia Animal, La Habana, Cuba

Carrillo, 0. 1971. Yeast digestion in pigs. Tesis M.Sc. Universidad de La Habana, Cuba.

Castro, M. 1976. Uso de distintos aditivos para mejorar la utilización de las dietas de miel final en la producción porcina. PhD Thesis. Instituto de Ciencia Animal, La Habana, Cuba

Castro, M., Díaz, J., Castañeda, J., Báez, L., Hernández, L., Ly, J., Cabrera, J. & Cino, D.M. 2002. A nutritional alternative as protein source for growing pigs: *Vigna unguiculata* cv INIFAT-93. Cuban J. Agric. Sci. 36:337

Castro, M., Díaz, J., Lezcano, P., Elías, A. & Iglesias, M. 1990. Feeding systems for fattening pigs fed molasses B diets and Saccharina feed. Cuban J. Agric. Sci. 24:93

Castro, M., Garrido, A. & Iglesias, M. 1985. The utilization of copper sulphate in growing-fattening pigs fed final molasses diets. Cuban J. Agric. Sci. 19:27

Díaz, J. 1977. Efecto del nivel de proteína en dietas de miel final sobre el crecimiento y reproducción de cerdos. Tesis Dr. C. Instituto de Ciencia Animal, La Habana, Cuba

Díaz., J., Casas, A. & Tuero, 0. 1985. Different levels of bermuda hay meal in final molasses diets for gilts. Cuban J. Agric. Sci. 19: 187

Díaz, J., Lezcano, P. & Román, B. 1989. Molasses B for lactating sow feeding. Cuban J. Agric. Sci. 23:14

Díaz, J., Elías, A. & Castañeda, S. 1990. A note on the use of different levels of final molasses and feed with Saccharina for pregnant sows. Cuban J. Agric. Sci. 24:195

Díaz, J. Castellón, A. & Román, B. 1997a. Saccharina levels during pregnancy and lactation of sows in the first two reproductive cycles. Cuban J. Agric. Sci. 31:55

Díaz, J., Castro, M., Pérez, N. & Achán, J. 1997b. A note on the bromatological composition of Saccharina from peeled or scraped sugar cane. Cuban J. Agric. Sci. 31: 295

Díaz, J., Elías, A. & Achan, J. 1996. A note on the study of Vitafert (sugar cane + poultry manure) levels in pre-fattening pigs. Cuban J. Agric. Sci. 30: 301.

Diéguez, F. & Menchaca, M. 1973. Performance test son pigs

fed maize or high-test molasses as the energy source. 1. Interrelationships among growth traits. Cuban J. Agric. Sci. 7:287

Elías, A. Lezcano, O., Lezcano, P., Cordero, J. & Quintana, L. 1991. Reseña descriptiva sobre el desarrollo de una tecnología de enriquecimiento protéico de la caña de azúcar mediante fermentación en estado sólido (Sacharina). Rev. Cubana de Cienc. Agric. 24:1

García, H. & Lezcano, P. 1987. Biological evaluation of some nutrients of the fleshings used as protein source for growing pigs. Cuban J. Agric. Sci. 21: 153.

Lamazares, E., Lezcano, P., Elías, A. & Valdés, E. 1988. Parcial sustitution of cereals by dehydrated sugar cane meal for prefattening pigs. Cuban J. Agric. Sci. 22:183

Lassota, L. 1969. Use of bagasse pith for decreasing diarrhea in pigs fed final molasses. Cuban J. Agric. Sci. 3:74

Lezcano, P. 1976. Utilización de levaduras cubanas como suplementos proteicos en dietas a base de mieles en la alimentación porcina. Tesis Dr. C. Instituto de Ciencia Animal, La Habana, Cuba

Lezcano, P. & Achang, J. 2002. Partial substitution of feeds by protein residues from alcohol distilleries for fattening pigs. Cuban J. Agric. Sci. 36:55

Lezcano, P. & Castañeda, S. 2000. A note on the partial substitution of concentrates by protein residues from alcohol distilleries for pre-fattening pigs. Cuban J. Agric. Sci. 34: 37

Lezcano, P. y Castañeda, S. 2002. Nitrogen and energy balance in pigs fed different levels of residues from alcohol distilleries. Cuban J. Agric. Sci. 36:139

Lezcano, P. & Elías, A. 1975. Performance of pigs fed different levels of saccharomyces yeast substituting fish meal in molasses diets. Cuban J. Agric. Sci. 9:299

Lezcano, P., Elías, A., Lamazares, E. & Achán, J. 1990. Saccharina inclusion levels in feeds for pre-fattening pigs. Cuban J. Agric. Sci. 24:87

Lezcano, P., González, R. & Achan, J. 2004. Balance of nutrients in pigs fed fermented mud. Cuban J. Agric. Sci. 38: 389

Lezcano, P., González, R. & Achan, J. 2005. Partial substitution of wheat and soybean by anaerobic swine muds for the feeding of growing fattening pigs. Cuban J. Agric. Sci. 39:193

Ly, J. 1971. Contribución al estudio de la digestión de mieles en el cerdo joven. Tesis de Maestría. Universidad de La Habana, La Habana, Cuba

Ly, J. 1974. Peripheral circulation of hexoses during the digestion of high-test molasses in the pig. Cuban J. Agric. Sci. 8:53

Ly, J. 1984. Pig fattening with sugar cane molasses. 2. Digestibility indices and passage along the gastrointestinal tract. Cuban J. Agric. Sci. 18:163

Ly,J. 1985. Large intestine digestion of pigs fed molasses. 2. Passage of digesta. Cuban J. Agric. Sci. 19:35

Ly, J. & Castro, M. 1984. Pig fattening with sugar cane molasses. 1. Performance traits and consumption pattern. Cuban J. Agric. Sci.18:35

Ly, J. & Castro, M. 1995. Studies on the utilization of different types of Saccharina for pigs. N and energy balance. Cuban J. Agric. Sci. 29:191

Ly, J. & Díaz, J. 1979. The use of high-test molasses for weaning piglets. 2. Some digestive indices. Cuban J. Agric. Sci. 13:39

Ly, J. & Lezcano, P. 1980. A note on the digestibility by growing pigs of certain nutrients and energy in maize on molasses-based diets.Trop. Agric. (Trinidad) 57:91

Ly & Pok, S. 2004. Use of mulberry foliage for pigs in the integrated tropical system. Cuban J. Agric. Sci. 48:63

Ly, J. & Velázquez, M. 1970. Some observations on blood glucose levels in pigs given dits based on final molasses and sugar, high-test molasses or grain. Cuban J. Agric. Sci. 4:195

Martínez, M. 2011. Evaluación de los granos de destilería secos con solubles en la alimentación de cerdos en crecimiento y reproductoras porcinas. Tesis Dr. C.

Martínez, M., Castro, M., Savón, L., Ayala, L., Castañeda, J., Hernández, L. and Achan J. 2010. Effect of distiller's dried grain with solubles (DDGS) on the excretion of nutrient in growing pigs. Cuban J. Agric. Sci. 44:379

Martínez M., Castro, M., Savón, L. Lázara, A., Castañeda, J., Hernández, L. & Achan, J. 2008. Assessment of distiller's dried grains with solubles (DDGS) in the productive performance and health indicators of growing pigs. Cuban J. Agric. Sci. 42: 387

MacLeod, N.A., Preston, T.R, Lassota, L.A., Willis, M.B. & Velázquez, M. 1968. Molasses and sugar as energy sources for pigs. Cuban J. Agric. Sci. 2:205

Marrero, L. & Díaz, C.P. 1976. The use of final molasses and rice by-products in diets for growing pigs. Cuban J. Agric. Sci. 10:161

Marrero, L. &Ly, J. 1976. Effect of different proportions of high-test molasses in diets for growing pigs. 1. Performance and carcass composition. Cuban J. Agric. Sci. 10:41

Marrero, L. & Ly, J. 1977a. Miel rica y miel final para cerdos en crecimiento. Digestibilidad de nutrientes, energía y retención de agua. VI Reunión ALPA. p. 121

Marrero, L. & Ly, J. 1977b. Digestibilidad y tiempo de retención de digesta en cerdos alimentados con miel rica y miel final. VI Reunión ALPA p. 120

Marrero, L. & Ly, J. 1977c. An approach to water metabolism in pigs fed sugar cane final molasses. 1. Main routes of water excretion and digestibility of proximal nutrients. Cuban J. Agric. Sci. 11:39

Preston, T.R. & WiIlis, M.B. 1969.Azúcar de caña como fuente de energía para la producción de carne. Comunicación Técnica No.2. Instituto de Ciencia Animal, La Habana, Cuba. p. 22

Rodríguez, N., Boucourt, R., Lamazares, E. & Larduet, R. 1989. Índices del patrón de consumo en lechones alimentados en dietas de harina de caña. Rev. Cubana Cienc. Agric. 23: 299

Rodríguez, N., Boucourt, R. & Riverí, S. 1988. Digestive indicators in pigs consuming high final molasses levels with the addition of fiber. 1. Apparent digestibility. Cuban J. Agric. Sci. 22:73

Rodríguez, N., Boucourt, R., Terry, I. & Elizarde, S. 1991. Indicadores digestivos del tracto de cerdos destetados que consumen harina de caña deshidratada. Rev. Cubana Cienc. Agric. 25:47

Rodríguez, Z. 2004. Uso del boniato (*Ipomoea batata* Lam) en la tecnología de fermentación en estado sólido de la caña de azúcar (*Saccharum officinarum*). Tesis Dr. C. Instituto de Ciencia Animal, La Habana, Cuba

Savón, L. 1984. Algunos aspectos del metabolismo mineral en cerdos alimentados con miel finaI. Tesis Dr.C. Instituto de Ciencia Animal. La Habana, Cuba

Savón, L., Alvarez, R.J., Díaz, C.P., Martínez, G. & Iglesias, M. 1989. Blood electrolytes in pigs fed final molasses and a modified mineral premix during the fattening period. Cuban J. Agric. Sci. 23:181

Savón, L, Alvarez, R.J., Larduet, R. & Martínez, G. 1987. Blood electrolytic composition and acid base balance in pigs fed high levels of sugar cane final molasses. Cuban J. Agric. Sci. 21:273

Velázquez, M. & Díaz, J. 1987. Alimentación de puercas y cochinatas con mieles como fuente de energía. La melaza como recurso alimenticio para la producción animal. Fundación Internacional para la Ciencia, Camagüey, Cuba

Velázquez, M., Dubé, F. & Cruz,N, 1978. Estudio comparativo de cerdas alimentadas durante la gestación con miel final o cereales como fuente de energía. Cienc. Téc. Agric. Ganado Porcino l (l):21

Velázquez, M. & Preston, T.R. 1970. High-test and integral molasses as energy sources for growing pigs. Cuban J. Agric. Sci. 4:55

Velázquez, M. & Preston, T.R. 1973. Protein levels in molasses-based diets for fattening pigs. Cuban J. Agric. Sci. 7:323

Received: September 10, 2014