ORIGINAL ARTICLE

Evaluation of Technology for the Small-Scale Production of Pelleted Feed for Rabbits

Evaluación de tecnología para la producción a pequeña escala de alimento peletizado, para conejos

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ABSTRACT: In the present investigation, an agro-industrial technology was developed for the small-scale production of pelleted feed for rabbits destined for the Rabbit Program of the Scientific-Productive Pole (PCP) of Quivicán Municipality, Mayabeque Province, based on the foundation of the functional requirements of the technology, the operational parameters and the work premises. The results showed that it was possible to cover the demand for pelletized feed of the PCP. Technology uses national raw materials produced in the PCP itself, with a procedure for obtaining a food that meets the nutritional requirements of rabbits. An agro-industrial technology capable of producing 200 kg/h was established, provided with a reception, storage, weighing, dosing, mixing and transportation, as well as with pelletizing and drying system, which guarantees a continuous flow of raw materials with a productive capacity of 1.2 t in 8-hour days. An innocuous food with a stable chemical composition is obtained, without generating contaminants to the environment. Due to the production levels obtained with the technology, it is necessary to contribute with the sale of pelletized feed to the different productive forms in Quivicán territory, as part of the Local Self-Supply Program.

Keywords Operational Parameters, Raw Material, Feed, Local Self-sufficiency.

RESUMEN: En la presente investigación se desarrolló la tecnología agroindustrial para la producción a pequeña escala de alimento peletizado para conejos con destino al Programa Cunícola del Polo-científico-productivo (PCP) del municipio de Quivicán de la provincia de Mayabeque, a partir de la fundamentación de los requerimientos funcionales de la tecnología, los parámetros operacionales y las premisas de trabajo. Los resultados demostraron que se logró cubrir la demanda de alimento peletizado del PCP. Tecnología que utiliza materias primas nacionales y producidas en el propio PCP, con procedimiento de obtención que permite alcanzar un alimento que cubre requerimientos nutricionales en los conejos. Se estableció una tecnología agroindustrial capaz de producir 200 kg/h, provista de sistema de recepción, almacenaje, pesaje, dosificación, mezclado, transportación, peletizado y secado, que garantiza un flujo continuo de las materias primas con una capacidad productiva de 1,2 t en jornadas de 8 h. Se obtiene un alimento inocuo de composición química estable, sin generar contaminantes al medio ambiente. Por los niveles de producción obtenidos con la tecnología se debe contribuir con la venta de pienso peletizado a las diferentes formas productivas del territorio de Quivicán, como parte del Programa de Autoabastecimiento Local.

Palabras clave: parámetros operacionales, materia prima, pienso, autoabastecimiento local.

INTRODUCTION

Globalization, the growth of the world population, climate change and the production of biofuels are factors that have currently reduced the availability of most foods, whether for human or animal consumption (FAO, 2013). In the year 2050, the world population will increase to 9.5 billion inhabitants, the competition for food between man and animals will increase and the negative impact of climate change will grow to produce cereals efficiently (FAO, 2017a). Some 2 billion people are food insecure (FAO, 2017a; 2017b; 2017c; 2017d).

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Food is a chain of events that begins with the cultivation, selection and preparation of food, up to the forms of presentation and consumption. There are many variants that exist worldwide for the production of protein of animal origin, rabbit is not exempt from it, estimating a world production of 1,200,000 t of meat, of which 43.6% (525,000 t) comes from industrialized units. Among the largest producers are Italy, France, Russia, China and Spain, which, together with Belgium, Portugal, Poland, the Netherlands and the Czech Republic, account for 80% of world production.

The global epidemiological situation caused by the pandemic caused by the new SARS-Cov-2 coronavirus has increased the international economic crisis, which, together with the intensification of the blockade imposed by the United States on Cuba, places the country in a complex economic situation. It evidences the need to seek sustainable alternatives to continue advancing in strategic sectors such as food production that is one of those prioritized in the National Plan for the Economy, drawn up until 2030. The abovementioned and the production of biofuels have brought about a vertiginous increase in the prices of energy grains (corn) and protein grains (soy) in the international market. According to reports from FAO 2017b), concentrate prices are currently high, and the average values of corn and soybeans are 219.0 and 460.5 USD per ton, respectively (BCC-Cuba, 2021). For these reasons, meat production becomes unsustainable, which motivates the introduction of other foods that lower production costs (Lezcano *et al.*, 2015). The patterns of food production and consumption that currently predominate in the richest countries are spreading throughout the world. In 1996, malnutrition affected 800 million people, which corresponds to the 13% of the world population (FAO, 2017d).

One of the priorities of the Cuban Revolution has been to feed the people and several programs have been developed to guarantee the production of the necessary items in the diet, fundamentally that linked to the consumption of animal meat. The main objective has been to ensure the quantity and quality of livestock production, where the development of minor species has always been, including rabbits. In Cuba, more than 2,000 million dollars are dedicated to the purchase of food abroad and many actions have been carried out to guarantee food for the population, even when the high prices in the international market are known. Working for the substitution of imports and generating income in Freely Convertible Currency (MLC) are permanent actions.

Rabbit breeding is one of the most economical farms in the tropics. In Cuba, the breeding of this species is increasing and with it the need and demand to enrich the knowledge of rabbit farmers in terms of feeding. Nutrition represents 80% of production costs in rabbit farms. This species can be fed with forage and industrial by-products and use the feed as supplements (pelletized or not) and not as basic foods of the diet.

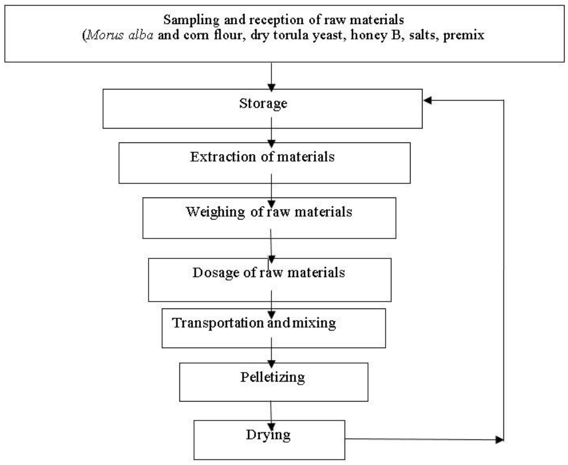

FIGURE 1. Simplified diagram of the technological process to obtain pelleted feed.

Achieving sustainable feeding for rabbit fattening in periods of less food availability guarantees greater food production in less volume and is the objective of industrial technology for the small-scale production of pelleted feed for rabbits.

Therefore, the general objective of this work was to develop a technology for the small-scale production of pelleted food for rabbits.

MATERIALS AND METHODS

The agro-industrial technology was developed for the small-scale production of pelleted feed for rabbits destined for the Scientific-Productive Pole Rabbit Program (PCP) of Quivicán Municipality in Mayabeque Province, based on the foundation of the functional requirements of the technology, operational parameters and work premises.

Figure 1 shows a simplified scheme of the technological process for obtaining pelletized feed in the PCP. The process begins with the sampling and reception of the raw materials to be stored. Previously, the flours were elaborated from protein bushes (*Morus alba, Moringa oleifera, Tithonia diversifolia*), taking into account the cutting age (56-60 days in rainy periods and 70 days in the dry one) for better use of its potential and the particle size in the grinding (3±1mm).

The raw materials are weighed before starting the process and observation tests are carried out to them, all are dosed to the mixer from greater to lesser volume and finally the honey is added. When the mixture of all the raw materials is homogeneous, it is transported to the pelletizing machine, since it is the latter that obtains the small cylinders or spheres, which are aerated for 12 hours for later storage.

The technological process is carried out in batches, where each equipment is selected to guarantee the process without interruptions and they are located in a position that avoids cross-contamination between raw materials and the finished product.

The potential capacity (200 kg/h) is determined taking into account that among the working premises is that the agribusiness produces 1.2 t in 8-hour days, but the equipment will be used only 6 hours for the years of exploitation of some of its components. This production is limited by the pelletizing capacity; therefore, the pelletizing machine is the one that restricts the production of the food. The guarantee of raw materials and the distance from supply sources are other aspects to take into account when establishing potential capacity. Honey B and dry torula yeast depend on two different industrial processes within the sugar sector and demand small amounts in the year.

Selection Criteria of Pelletizing Machine

The pelletizing or granulating machine has the function of converting a mixture into small spherical or cylindrical pieces (granules or pallets), exerting pressure, using heat or incorporating humidity. They are used in different industrial processes, from the production of food, cosmetics, fertilizers, medicines and biofuels. The quality of the pellet depends not only on the raw materials and the process used, but also on the physical integrity during handling and transportation.

There are different types of pelletizing machines, which vary according to the operating principle they use to convert the mixture of raw materials into pallets. The most common are those with rotating rollers, disc, counter flow, flat and annular die. They can be stationary or mobile and electric or diesel. The extruder machines obtain pellets as a final product, but they have the capacity to transform the physical and chemical characteristics of the raw materials, something that favors the animal feed production industry.

The machine with rotating rollers (Figure 2) is selected for the pelleting of food in the PCP of Quivicán for rabbits, due to the production capacity, according to the scale of the proposed agribusiness and availability in the market. In this type of machine, the matrix remains fixed while the rollers rotate and press the material to the holes of the output matrix according to Behnke *et al.* (1997), achieving a pellet of high quality and density. This equipment is used for the small-scale production of high-density biomass pellets for animal feed or biofuels for boilers and furnaces.

The productive response by the rabbits will be given by the physical-mechanical characteristics of the pellets, the chemical composition, the breed and the handling of the species (Paneque *et al.*, 2018). When

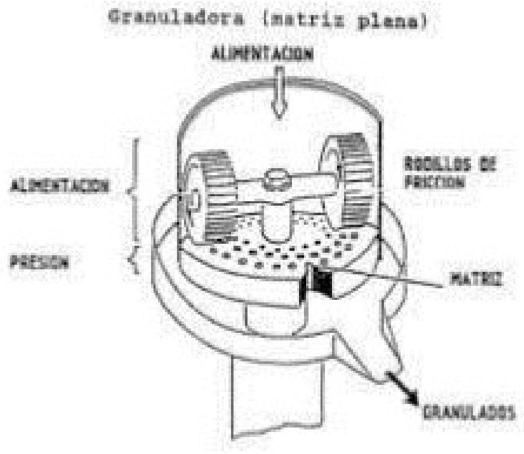

FIGURE 2. Simplified diagram of a roller pelletizer.

the diameter of the pellets ranges between 3.0 and 4.5 mm, an increase in feed consumption is observed, having higher conversion and as a consequence there is an increase in weight gains, which shows a better productive response. When the diameter is greater than 5 mm, feed losses increase in the feeders, which makes it difficult to consume food. When the diameter is less than 2.5 mm, the specific weight of the feed is reduced, and the productive indexes deteriorate. It is recommended to use the same diameter for females and fattening rabbits. The length of the pellets should be between 2 and 2.5 times the diameter, to give the granule more solidity (Camacho *et al.*, 2010).

Determination of the Main Chemical-Physical and Microbiological Characteristics of the Pellet

Nine pellet samples (1 kg each), from three different batches, are randomly selected. Chemical characterization is performed in the ICA laboratory, determining % MS, % CP and % FB.

Determination of the Main Physical-Mechanical Properties of the Pellet

To determine the physical-mechanical properties of the pellet (size: length and perimeter, volumetric mass) and visual examination, 9 samples taken at random from 3 different batches are used. The measurements are made in the ICA Engineering Area, at an average temperature of 30.9 °C, atmospheric pressure of 102.48 kPa, relative humidity of 73.1% and an average DM of 87% in the different batches.

All sample sizes are selected, based on the statistical tables proposed by Menchaca & Torres, (1985), for the classic experimental designs, and what Mora (2012) proposed. Position statistics are determined to data with the statistical package Infostat version 2012, according to Di Rienzo *et al.* (2012) and the analyses are carried out according to the methodology described (Páez *et al.*, 2016).

Equipment Used in Studies at the Laboratory Level

To determine the percentage of dry matter (% DM), a Boxun thermostatic oven is used in the laboratory, with a temperature of 250 ± 5ºC and a precision of 0.1°C.

To determine the percentage of crude protein (% CP), a Kjeldahl nitrogen digester is used, with a precision of ± 0.5 °C.

To determine °Brix, a digital refractometer with a precision of 0.5 ºC is used, and for density, a densitometer with an accuracy of 0.001 g/cm^3.

Size is determined using the methodology described by Camacho *et al.* (2010) and for this, a Vernier caliper is used (range 0-100 mm) with a precision of 0.05 mm.

Regarding the hygienic-sanitary quality, the standards NC- 120 4832 (2002); NC-120 7954 (2002), To determine the volumetric mass of the pellet, the methodology used by Valdés (2003) was followed, and for this, 500 kg of pellet were selected. A digital platform scale (GADGETS) with a maximum capacity of 500 kg and a precision of 100 g and a cylindrical container made of galvanized sheet No. 14 of 0.5 m³ is used. The pellets that fit in the container are measured for their mass with the scale and the results of the experiment are determined by the volumetric mass of the pellet.

$$\gamma = \frac{Q}{V}$$

where:

γ - volumetric mass, t/m^3;

Q - sample mass, t;

V - volume occupied by the pellets in the container, (0.5 m^3).

The density of the pellets is determined according to the methodology described by Iglesias & Soto (1987) and to carry it out, 1 kg of pellets is selected, determining their mass with a Scout Pro technical balance with a precision of 0.01 g. The pellets are immersed in a 1 L graduated cylinder, with 1 cm³ precision.

With the difference in the volume of water (ΔVb) displaced by the pellets, the density is determined for each test, using the expression:

$$Pb = \frac{msb}{\Delta Vb}$$

where:

ρb - pellet density, g/cm^3;

msb - mass of pellets, g;

ΔVb - pellet volume, cm^3.

Determination of the Main Times of Operations of the Agribusiness

The times of agribusiness operations were selected taking into account the criteria used by Behnke *et al.* (1997 and Zinn (2002). Establishing as main, the times:

- Raw material sampling time
- Weighing time
- Dosing time
- Mixing time
- Transportation time
- Pelletizing time
- Drying time
- Bagging time
- Storage time.

To determine the operating times, an Oregon Scientific brand digital chronometer, Model SL210, from zero to 24 h and precision 0.01 s, is used. Ten repetitions are performed.

To determine the mixing time, an experiment was designed, which is carried out in the PCP agribusiness.

TABLE 1. Main chemical characteristics of the pellets

Indicators	Value
MS %	88,11
PB% BS	16,3
FB% BS	6

BS: Dry basis

RESULTS AND DISCUSSION

All laboratory studies were carried out at a temperature of 20.4±2°C and a relative humidity of 76±3%.

The chemical characteristics of the pellets are shown in Table 1. As it can be seen, the MS value is above 85%. The DM of each of the raw materials (mulberry flour, whole corn flour, dry torula yeast, mineral premix and salt) is high and makes up 90% of the formulation.

The DM contents can vary according to the characteristics of the raw materials and for those that are made in the PCP they can vary by the type of crop, selected agricultural production system and agronomic management practices (Castillo *et al.*, 2014; Gauna & Zequeira, 2014). The cutting age (mulberry) or the harvest (corn), the incidence of diseases and the type of drying are other factors that influence the DM of the pellets (Rodríguez, 2011). The DM content (88.11%) is high, with values similar to those of the flours and other sources used in the formulation. Honey B has low CP content, which, being only 10% in the formulation, does not affect the protein content of the pelleted feed. The CP value (16.33%) is high, which may be associated with mulberry flour (CP, 19.01%) and dry torula yeast (CP, 46.2%).

Regarding the hygienic-sanitary quality, it can be highlighted that the microbiological analyses consolidate its innocuousness and the use in large quantities of animals. Their results were in the range of the indicators established in the 53 standards NC-120 4832 (2002); NC- 120 7954 (2002), with no growth of bacteria and the total count of fungi (1.1 E3) was below that referred to in the NC.

Main Physical-Mechanical Characteristics of the Pellets

The physical-mechanical characteristics show a size of small dimensions and regular shape, being feasible its handling, distribution and consumption (Table 2).

Main Chemical-Physical Characteristics of Honey B

Honey B during the experimental stage, presented (Table 3) a percentage of DM of minimum value (79%), being in the lower limit recommended by the Branch Standard of MINAZ Minaz-Cuba (2007). It is considered a food with a high percentage of DM and with adequate chemical characteristics for its use in animal feed.

Mix Time Result

The mixing time is 25E-2 h (Figure 3), which may be due to the presence of 10% of honey B, causing particle agglomeration during the mixing process.

Results of the Operation Times of the Agribusiness

The main operational times of the agribusiness are shown in Table 4. The sampling time of the raw materials should not be carried out daily; it is only carried out when these are supplied to the agribusiness. The weighing of the raw materials is carried out before each run, being an action that can be performed as the mixture is mixed, transported or pelletized. This action is in correspondence with the skills of the operator.

In the dosing of the raw materials to carry out the mixing process, most of the time is concentrated in the dosing of the mulberry flour and the whole corn flour, as they are the ones with the largest volume to occupy in the mixer. Honey B is the last to dose the mixer and is done manually from the platform, place that is provided with railings for the safety of personnel working in the agribusiness.

The mixing process takes approximately 15 minutes, it begins with the dosage of the whole corn flour, then the mulberry flour, to continue with the torula yeast, the salt and the mineral premix, finally dosing the honey B .

Mulberry flour was made from the whole plant (leaves and stems), ground and spread on a drying plate, exposed to the sun for 48 to 72 h, until humidity was reduced to less than 15%.

TABLE 2. Main physical-mechanical characteristics of the pellets

Indicators	Measures
Length (mm)	29
Size perimeter (mm)	12.36
Volumetric mass (t/m^3)	0.375
Density (g/m^3)	0.375

TABLE 3. Main chemical-physical characteristics of honey B

Indicators	Value
MS (%)	79
Brix	79
P (kg/m^3)	1400

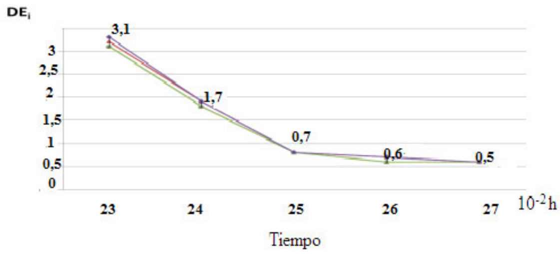

FIGURE 3. Curve for determining the mixing time.

TABLE 4. Main operational times

Time of operations per tons (h)	Mean (n=5)
Sampling of raw materials, h	26.6E-2
Weighing of raw materials, h	18.33E-2
Dosage of raw materials, h	11E-2
Mixed, h	25E-2
Transportation, h	20E-2
Pelletized, h	33.3E-2
Drying, h	12
Bagging, h	2.5
Storage, h	33.3E-2

CONCLUSIONS

- A small-scale agribusiness technology was established in Mayabeque Province, capable of producing 200 kg/h of pellets, provided with a reception system, storage for bagged and liquid raw materials, mixing, transportation, pelletizing, from the Foundation of the functional requirements of the technology and the operational parameters for the agribusiness production of pelleted feed.
- The proposed technology satisfies the demand for pelleted feed for consumption by the Quivicán PCP rabbit program, which needs 0.25 t/d of pelleted feed, for 1,000 breeders with their offspring (4 rabbits per litter) and 100 stallions. .
- With the establishment of the technology, 1.2 t/d of pellets can be produced, for 300 days a year, for a total of 360 t a year, without generating contaminants to the environment.

- Due to the production levels achieved with the proposed technology, it is possible to contribute with the sale of pelletized feed to the different productive forms of Quivicán territory as part of the local self-sufficiency, leaving coverage for 10 days (2.5 t) in the PCP.
- The pelletized food obtained on a small scale is safe because the results: total bacterial count (no growth), and total fungal count (1.1 E3), guarantee the hygienic-sanitary quality according to the standards established for the microbiological analyses and consolidating its use in large numbers of animals.

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