

## Crude glycerin reduces electricity consumption and improves pellet quality of broiler feed

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### ADDITIONAL KEYWORDS

Chicken feed.  
Power consumption.  
Pellet quality.  
Pelleting process.

### SUMMARY

This study aimed to evaluate the effect of different crude glycerin inclusions on the pelleting process and quality of pelleted feed for broilers in the initial (7–21 d) and growth (22–42 d) phase. The experimental diets were evaluated through variables such as electricity consumption (KWh/t), pelleting productivity (t/hour), Pellet Durability Index (PDI) and pellet temperature (°C). To accomplish the goals, an experimental randomized block design was applied, with four treatments (0, 4, 8 and 12% crude glycerin) and five repetitions of 250 kg feed. During each repetition at pelleting, energy consumption (kWh/t) was calculated using time and amperage data. Regression analysis was performed after the ANOVA results. In both types of processed feeds, there was significant ( $P<0.05$ ) linear decrease in the electricity consumption (kWh/t), when diet was pelleted with increasing levels of crude glycerin. However, no significant effect ( $P>0.05$ ) in pelleted feed produced per hour was observed. A linear increase ( $P<0.05$ ) was though found in PDI and quadratic effect ( $P<0.05$ ) regarding temperature of the produced pellets. We conclude that the crude glycerin is an effective enhancer of pelleting process once it improved the pellet quality and reduced electricity consumption at the feed mills.

### La glicerina cruda reduce el consumo de electricidad y mejora la calidad del pellet del pienso para pollos de engorde

### RESUMEN

Este estudio tuvo como objetivo evaluar el efecto de diferentes inclusiones de glicerina cruda en el proceso de granulación y la calidad del pienso granulado para pollos de engorde en la fase inicial (7–21 días) y de crecimiento (22–42 días). Las dietas experimentales se evaluaron mediante variables como consumo de electricidad (KWh/t), productividad de peletización (toneladas/hora), Índice de Durabilidad del Pellet (IDP) y temperatura del pellet (°C). Para lograr los objetivos se aplicó un diseño experimental de bloques al azar, con cuatro tratamientos (0, 4, 8 y 12% de glicerina cruda) y cinco repeticiones de 250 kg de pienso. Durante cada repetición de granulación, se calculó el consumo de energía (kWh/t) utilizando datos de tiempo y amperaje. El análisis de regresión se realizó después de los resultados de ANOVA. En ambos tipos de piensos procesados, hubo una disminución lineal significativa ( $P<0,05$ ) en el consumo de electricidad (kWh/t), cuando la dieta se peletizó con niveles crecientes de glicerina cruda. No se observó ningún efecto significativo ( $P>0,05$ ) en la producción de pienso granulado por hora. Sin embargo, se encontró un aumento lineal ( $P<0,05$ ) en el IDP y un efecto cuadrático ( $P<0,05$ ) con respecto a la temperatura de los pellets producidos. Concluimos que la glicerina cruda mejoró la calidad del pellet y redujo el consumo de electricidad en las fábricas de piensos.

### PALABRAS CLAVE

Pienso para pollos.  
Consumo de energía.  
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Proceso de peletización.

### INFORMATION

Cronología del artículo.

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## INTRODUCTION

Brazil holds the world leadership in chicken meat exports (32%) and third place (15%) in the world chicken meat production (Embrapa, 2021). In order to maintain this position, Brazilian poultry sector faces great challenges, such as the production cost, because animal nutrition accounts for nearly 70% of all production costs (Embrapa, 2021).

The biggest challenge of animal nutrition refers to the diet composition, based on corn and soybean meal, known to compete with human diet (Pereira et al., 2016). Also, these commodities are mainly directed to produce renewable energy. Other issue is diet cost due to fluctuation in the cost of feed ingredients (Ahumada and Cornejo, 2016). Therefore, ingredients that enable good levels of productive performance at low cost are constantly being pursued. The use of co-products or by-products in animal feed helps reducing costs and increasing flexibility in diet formulation (Wu et al., 2020; Biedenbach, 2021).

Crude glycerin (CG) is a by-product from the biodiesel production (composed of glycerol, water and methanol) and is classified as a dietary energy source, which can be used to replace corn in broiler diets. Since 2008, the mandatory blending content of biodiesel in fossil diesel oil raised from 2% to 10%, as established by the National Energy Policy (BRASIL, 2021; ANP, 2023). Therefore, glycerin production is also increasing.

Crude glycerin is regularly employed as a wetting additive, but studies demonstrate the possibility of using it as an energy source in broiler diets, resulting in savings in diet formulation (Boonwong, Wattanachant and Wattanasit, 2018; Tavernari et al., 2022). The wetting property of glycerin is related to the improvement in the feed pelleting process (Groesbeck et al., 2008; Kholif, 2019), as it enhances starch gelatinization and reduces friction in the pelleting process. Interestingly, CG inclusion in diet favored serum concentrations in pregnant sows, thereby regulating hormones, suggesting a relation between diet composition and hormone concentration (Hernández et al., 2016).

The concern with the destination of agro-industrial waste grows every day and the recycling and/or reuse of this waste benefits the society, the environment, and reduces production costs. The great challenge of poultry farming is combining high productivity and competitiveness with social and environmental responsibility (Pacheco, Moita Neto and Da Silva, 2018). Thus, the current ongoing production of crude glycerin associated with this challenge make the use of this biodiesel co-product interesting both in feed mills and in the pelleting process, once it may enhance the pellet quality. According to these mentioned facts, the objective of this study was to evaluate the effect of CG addition in different levels on the pelleting process and pelleted diet quality intended for broilers in the initial (7-21 days) and growth (22-42 days) phases.

## MATERIALS AND METHODS

Two experiments were carried out. In the first one, the feed pelleting process was intended for the initial phase (7–21 days), while the second for the growth phase (22–42 days). The diets were formulated (Tables I and II) to meet the recommendations proposed by Rostagno et al. (2017). At pelleting process, a steam pelletizer (Koppers Júnior C40) with a 50 HP motor (Siemens) and pelleting die with 3/16-inch diameter holes was utilized.

A randomized block design was applied, with four treatments (0, 40, 80 and 120 g/kg crude glycerin inclusion) and five repetitions, of 250 kg feed, for each evaluated phase. Prior to pelleting process, the feeds were homogenized in a vertical mixer. The blocks were constituted by one repetition of each treatment by feed passage through the pelletizer, as a function of time. For cleaning purposes, among each pelleting treatment, 50 kg of ground wheat bran were passed through the pelletizer. The crude glycerin used was from soybean oil and its composition was 80.0% glycerol, 870 g/kg DM, 40 g/kg Cl, 24 g/kg Na and 3563 kcal/kg of crude energy.

To determine the energy consumed (KWh/t) by the pelletizer during each repetition, the following measurements were made: Amperage, which consisted of reading the ammeter from the beginning to the end of the pelletization, at spaced times; Pelleting time, where each repetition was timed for the calculation of energy consumption (KWh/t), using the equations 1 and 2:

$$I=P/V \quad (1)$$

$$KWh=(P \times \text{Pelleting time (hour)})/1000 \quad (2)$$

Where I = Amperage, P = Power (W), V = Tension ( $380 \times \sqrt{3}$ ).

For the evaluation of the pellet durability index (PDI), from each of the five repetitions, four sub-samples, with approximately 700 g each, were collected before cooling. These sub-samples passed through a sieve with an opening size slightly smaller than the diameter of the pellets (4 mm) and then 500 g of pellets retained in the sieve were placed in the apparatus for durability testing.

All samples were processed for 10 minutes at 50 rpm and after this time, the sample was removed from the PDI determination apparatus and passed again through a sieve with 4 mm diameter openings. To quantify the pellets retained in the sieve, the pellets were weighed, and the durability was calculated using the equation 3:

$$\text{Durability (\%)} = (\text{weight of pellets after the test}) / (\text{weight of pellets before the test}) \times 100 \quad (3)$$

The temperature and humidity during processing were registered to confer the pellet temperature.

The data on the pellet durability index and energy consumption of the pelletizer were analyzed using descriptive analysis, to verify the presence of outliers.

The regression analysis was performed after ANOVA results at 5% probability ( $P < 0.05$ ) by using SAS (Sas Institute Inc, 2012) statistical software.

**Table I. Experimental diets (Initial phase: 7–21 days)** (Dietas experimentales (Fase inicial: 7-21 días)).

| Ingredients (g/kg)          | Levels of crude glycerin inclusion (g/kg) |        |        |        |
|-----------------------------|-------------------------------------------|--------|--------|--------|
|                             | 0                                         | 40     | 80     | 120    |
| Corn                        | 573.2                                     | 529.2  | 485.3  | 436.5  |
| Soybean meal                | 362.9                                     | 370.2  | 377.6  | 385.8  |
| Glycerin                    | 0                                         | 40     | 80     | 120    |
| Soybean oil                 | 25.4                                      | 24.5   | 23.6   | 24.3   |
| Calcitic limestone          | 9.2                                       | 9.2    | 9.1    | 9.1    |
| Dicalcium phosphate         | 15                                        | 15     | 15.1   | 15.1   |
| Salt                        | 4.8                                       | 2.4    | 0      | 0      |
| L-Lysine HCl                | 1.7                                       | 1.6    | 1.4    | 1.3    |
| DL-Methionine               | 2.7                                       | 2.8    | 2.8    | 2.9    |
| L-Threonine                 | 0.4                                       | 0.4    | 0.4    | 0.4    |
| Adsorber                    | 2.0                                       | 2.0    | 2.0    | 2.0    |
| Vitamin premix <sup>1</sup> | 1.0                                       | 1.0    | 1.0    | 1.0    |
| Mineral premix <sup>2</sup> | 0.5                                       | 0.5    | 0.5    | 0.5    |
| Choline chloride 60%        | 1.0                                       | 1.0    | 1.0    | 1.0    |
| Tylan 40                    | 0.1                                       | 0.1    | 0.1    | 0.1    |
| BHT <sup>3</sup>            | 0.1                                       | 0.1    | 0.1    | 0.1    |
| Total                       | 100.00                                    | 100.00 | 100.00 | 100.00 |
| Calculated composition      |                                           |        |        |        |
| Crude protein (g/kg)        | 212.6                                     | 212.5  | 212.4  | 212.2  |
| ME <sup>4</sup> (kcal/kg)   | 3000                                      | 3000   | 3000   | 3000   |
| Crude fiber (g/kg)          | 29.1                                      | 28.8   | 28.4   | 28.0   |
| Na (g/kg)                   | 2.1                                       | 2.1    | 2.1    | 3.0    |
| Digestible lysine (g/kg)    | 11.7                                      | 11.7   | 11.7   | 11.7   |

<sup>1</sup> Mineral premix (kg of product): Fe – 100 g; Cu – 20 g; Co – 2 g; Mn – 160 g; Zn – 100 g; I – 2 g.

<sup>2</sup> Vitamin premix (kg of product): vit. A – 9.000.000 U.I.; vit. D<sub>3</sub> – 2.500.000 U.I.; vit. E – 20.000 U.I.; vit. B<sub>1</sub> – 1.5 g; vit. B<sub>2</sub> – 6.0 g; vit. B<sub>6</sub> – 3.0 g; vit. B<sub>12</sub> – 0.012g; Pantothenic acid – 12.0 g; Biotin – 0.06 g; vit. K<sub>3</sub> – 2.5 g; Nicotinic acid – 25.0 g; Se – 250.0 mg.

<sup>3</sup> Butyl hydroxytoluene antioxidant.

<sup>4</sup> Apparent metabolizable energy.

## RESULTS

In the pelleting process of the initial and growth feed phase (Table III), a linear decrease ( $P < 0.05$ ) in the energy consumption (KWh/t) was observed as the levels of crude glycerin (CG) increased. As the inclusion of glycerin in the initial feed phase increased, a reduction in consumption (KWh/t) was seen compared to the control treatment (without glycerin) in 15.6, 11.3 and 20.4% and for the growth phase the reductions were 10.1, 20.0 and 22.5%, by adding 40, 80 and 120 g/kg of CG, respectively.

The inclusion of CG did not influence the pelletizer productivity (tons of pelletized feed per hour - t/h)

with no effect ( $P > 0.05$ ) for both initial and growing phase feed types. There was a linear increase in the PDI ( $P < 0.05$ ) with the inclusion of CG in the diets of the two phases.

There was no effect of the CG addition in the initial phase for pellet temperature and there was a quadratic effect with a minimum point ( $P < 0.05$ ) in the growth phase, which indicates that CG use even in different amounts in the diets, does not influence yield (t/h) in the pelleting process. However, this should be better evaluated during the feed flow in the silos.

**Table II. Experimental diets (Growth phase: 22–42 days)** (Dietas experimentales (Fase de crecimiento: 22-42 días)).

| Ingredients (g/kg)          | Levels of crude glycerin inclusion (g/kg) |        |        |        |
|-----------------------------|-------------------------------------------|--------|--------|--------|
|                             | 0                                         | 40     | 80     | 120    |
| Corn                        | 620                                       | 576    | 531.5  | 482.6  |
| Soybean meal                | 312.4                                     | 319.8  | 327.2  | 335.4  |
| Glycerin                    | 0                                         | 40     | 80     | 120    |
| Soybean oil                 | 34.3                                      | 33.3   | 32.6   | 33.4   |
| Calcitic limestone          | 8.3                                       | 8.2    | 8.2    | 8.1    |
| Dicalcium phosphate         | 11.8                                      | 11.8   | 11.9   | 12     |
| Salt                        | 4.5                                       | 2.1    | 0      | 0      |
| L-Lysine HCl                | 1.7                                       | 1.5    | 1.4    | 1.3    |
| DL-Methionine               | 2.4                                       | 2.4    | 2.5    | 2.5    |
| L-Threonine                 | 0.3                                       | 0.3    | 0.3    | 0.3    |
| Adsorber                    | 2.0                                       | 2.0    | 2.0    | 2.0    |
| Vitamin premix <sup>1</sup> | 0.8                                       | 0.8    | 0.8    | 0.8    |
| Mineral premix <sup>2</sup> | 0.5                                       | 0.5    | 0.5    | 0.5    |
| Choline chloride 60%        | 1.0                                       | 1.0    | 1.0    | 1.0    |
| Tylan 40                    | 0.1                                       | 0.1    | 0.1    | 0.1    |
| BHT <sup>3</sup>            | 0.1                                       | 0.1    | 0.1    | 0.1    |
| Total                       | 100.00                                    | 100.00 | 100.00 | 100.00 |
| Calculated composition      |                                           |        |        |        |
| Crude protein (g/kg)        | 193.2                                     | 193    | 192.9  | 192.7  |
| ME <sup>4</sup> (kcal/kg)   | 3120                                      | 3120   | 3120   | 3120   |
| Crude fiber (g/kg)          | 27.3                                      | 26.9   | 26.5   | 26.1   |
| Na (g/kg)                   | 2.0                                       | 2.0    | 2.1    | 3.0    |
| Digestible lysine (g/kg)    | 10.5                                      | 10.5   | 10.5   | 10.5   |

<sup>1,2,3,4</sup>-please refer to Table I legend.**Table III. Average electricity consumption by the pelletizer (KWh/t), productivity (t/h), pellet durability index (PDI) and pellet temperature of broiler diets for initial and growth phase with increasing crude glycerin levels** (Consumo medio de electricidad de la peletizadora (KWh/t), productividad (t/h), índice de durabilidad del pellet (IDP) y temperatura del pellet de dietas para pollos de engorde en la fase inicial y de crecimiento con niveles crecientes de glicerina bruta).

| Glycerin level (%)             | Energy consumption (KWh/t) | Productivity (t/h) | Pellet Durability Index (%) | Pellet temperature (°C) |
|--------------------------------|----------------------------|--------------------|-----------------------------|-------------------------|
| Initial feed phase (7–21 days) |                            |                    |                             |                         |
| 0                              | 17.08 ± 0.46               | 1.95 ± 0.11        | 80.19 ± 1.12                | 75.87 ± 0.25            |
| 4                              | 14.42 ± 0.51               | 1.62 ± 0.13        | 86.09 ± 0.67                | 74.19 ± 0.16            |
| 8                              | 15.13 ± 0.50               | 2.08 ± 0.11        | 91.20 ± 0.44                | 74.97 ± 0.42            |
| 12                             | 13.60 ± 0.21               | 1.82 ± 0.13        | 94.78 ± 0.16                | 74.60 ± 0.24            |
| P value                        | 0.0005 <sup>L</sup>        | 0.6853             | 0.0001 <sup>L</sup>         | 0.2314                  |
| CV <sup>1</sup> (%)            | 6.83                       | 13.37              | 2.72                        | 4.37                    |
| Growth feed phase (22–42 days) |                            |                    |                             |                         |
| 0                              | 17.36 ± 0.39               | 2.39 ± 0.08        | 54.75 ± 1.08                | 75.96 ± 0.41            |
| 4                              | 15.61 ± 0.77               | 2.28 ± 0.14        | 64.64 ± 1.82                | 72.84 ± 0.64            |
| 8                              | 13.88 ± 0.35               | 2.40 ± 0.18        | 78.26 ± 1.27                | 72.86 ± 0.50            |
| 12                             | 13.45 ± 0.37               | 2.54 ± 0.29        | 87.92 ± 0.82                | 74.21 ± 0.43            |
| P value                        | 0.0002 <sup>L</sup>        | 0.4973             | 0.0001 <sup>L</sup>         | 0.0001 <sup>Q</sup>     |
| CV <sup>1</sup> (%)            | 8.23                       | 17.25              | 8.07                        | 4.50                    |

<sup>L</sup> = linear.<sup>Q</sup> = Quadratic.<sup>1</sup> CV = Coefficient of variation

The pellet durability index (PDI) increased linearly ( $P < 0.05$ ) as the levels of CG in the diets increased, providing higher pellet quality. Regarding temperature ( $^{\circ}\text{C}$ ) of the pellets produced, there was a quadratic effect ( $P < 0.05$ ) of the CG level.

There was a significant ( $P < 0.05$ ) linear improvement in the durability index of the pellets, with less ground thin particles produced with the increase in CG levels, however there was a quadratic effect on the temperature of the pellets evaluated before cooling.

## DISCUSSION

Key factors associated with pellet production are its durability and operational cost of the pellet mill (Nielsen, Mandø and Rosenørn, 2020). The observed reduction in energy consumption (KWh/t) with the inclusion of CG is related to the wetting effect of glycerin, which induced a reduction in the friction of the feed in the pelleting process. As a result, a lower engine load (as indicated by decreased amperage) resulted in reduced electrical energy consumption during pellet production, regardless of the feed types (initial and growth phase). Similar results were found by Shields et al. (2012), who verified a reduction in the consumption of electricity in the pelleting process of pig feeds as CG was included in the feeds, an effect that the authors associated with the reduction of friction during the pelleting process.

The effect of glycerin on the pelletizer energy consumption and pellet durability was also studied by Groesbeck et al. (2008) when evaluating pig feed; they also observed a reduction in the consumption of electric energy by the pelletizer and an improvement in the pellet durability in diets with glycerin, compared to the use of oil or the mixture of oil with glycerin. The effect of using CG on production efficiency and energy consumption for pellet production was also observed in cattle feed production (Drouillard, 2012). Our results point to an important side effect of CG addition in poultry diets, which is a reduction of up to 22% in the electricity costs in the feed pelleting process.

These results demonstrate that, beyond its benefits for poultry feed, glycerin also helps lower pelleting process costs. Specifically, the reduction in energy expenses can decrease overall feed costs by up to 20.37% during the initial phase and 22.52% in the growth phase when compared to diets without glycerin.

The improvement in pellet durability observed when increasing CG addition in the diets is related to the wetting effect of glycerin, attributed to the improvement in starch gelatinization, reducing the breakage of the pellet during and after processing. The increase in the PDI achieved 18.23% (initial feed) and 60.58% (growth feed) compared to diets without the glycerin inclusion, which is in agreement with Madrid et al. (2013), that identified a linear improvement in the quality of the pig feed pellets with CG inclusion in the diets. This effect can result in significant gains in broiler performance, once diets with higher PDI are less likely to break during storage, transport and distribution in

feeders (Lorenzetti et al., 2019), as a consequence, less ground thin particles are generated.

The humectant capacity of glycerin and the lower friction in the pelleting process explain the quadratic effect observed in the temperature of pellets from the growth phase diet, which had an initial decrease, as the CG was included, with a slight increase in the higher levels inclusion. While pellet temperature increased with higher CG levels, it did not exceed the temperature of pellets from the control diet, even at 120 g/kg inclusion.

The productivity of the pelletizer was not affected by glycerin inclusion, which suggests that glycerin only reduced the pelletizer's effort in the pellet production (decreased energy expenditure - KWh/t), without altering the feed flow during the process inside the pelletizer. However, the feed flow in the silo should be evaluated, differently from the findings reported by Madrid et al. (2013), who identified an improvement of 20–29% in productivity, when compared to crude glycerin-free group.

## CONCLUSIONS

The inclusion of crude glycerin in broiler feed during initial and growth phase improved the characteristics of pellets and decreased the energy cost of pelleting process.

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