Effect of feeding *Manihot esculenta* Crantz on egg production in laying hens †

[Efecto de la alimentación con *Manihot esculenta* Crantz sobre la producción de huevo en gallinas ponedoras]

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SUMMARY

Background: Corn imported from the United States of America is used in southeastern Mexico to produce feed for laying hens. **Objective:** To evaluate *Manihot esculenta* Crantz (cassava) flour as a substitute for corn in feed for laying hens for egg production and quality. **Methodology:** A total of ninety 50-week-old hens with an average live weight of 1.512 ± 0.13 kg were randomly assigned to five dietary treatments containing 0%, 10%, 20%, 30% or 40% cassava flour, using a completely randomised design. **Results:** The highest feed intake was observed in hens fed the diet containing 40% cassava (P<0.05). Laying rate, eggs produced per day, egg weight, and feed conversion did not differ significantly between treatments (P > 0.05). Similarly, egg length, egg width, shell thickness, shell weight, albumen and yolk characteristics, and Haugh units did not differ between treatments (P>0.05). **Implications:** The results suggest that local egg producers could replace up to 82% of corn with cassava in laying hen diets, thereby reducing their dependence on corn imports. **Conclusion:** This study demonstrates that incorporating up to 40% cassava meal instead of corn in the diet of laying hens does not compromise egg production, egg quality, or the economic efficiency of egg production.

Key words: Cassava; feed intake; feed conversion ratio; egg quality.

RESUMEN

Antecedentes: Para la elaboración de alimento para gallinas de postura en el sureste de México se utiliza maíz importado de Estados Unidos de América. **Objetivo:** Evaluar la harina de *Manihot esculenta* Crantz (yuca) en sustitución del maíz en el alimento de gallinas ponedoras sobre la producción y calidad de los huevos. **Metodología:** Un total de noventa gallinas de 50 semanas de edad con un peso vivo promedio de 1.512 ± 0.13 kg fueron asignadas a cinco dietas con 0%, 10%, 20%, 30% y 40% de harina de yuca, utilizando un diseño completamente al azar. **Resultados:** El consumo más alto de alimento se observó en la dieta con 40% de yuca (P<0.05). El porcentaje de postura, el huevo producido por día, el peso del huevo y la conversión alimenticia no fueron diferentes entre tratamientos (P>0.05). La longitud del huevo, el ancho del huevo, el grosor de la cáscara, el peso de la cáscara, las características de la albúmina y la yema y las unidades Haugh no difirieron entre tratamientos (P>0.05). **Implicaciones:** Los resultados sugieren que los productores locales de huevos podrían sustituir hasta un 82 % del maíz por harina de yuca en la dieta de las gallinas ponedoras, reduciendo así su dependencia de las importaciones de maíz. **Conclusión:** Este estudio demuestra que incorporar hasta un 40% de harina de yuca en lugar de maíz en la dieta de las gallinas ponedoras no compromete la producción, la calidad ni la eficiencia económica de la producción de huevos.

Palabras clave: Yuca; consumo de alimento; conversión alimenticia; calidad del huevo.

† Submitted March 13, 2025 – Accepted July 3, 2025. http://doi.org/10.56369/tsaes.6240

ISSN: 1870-0462.
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INTRODUCTION

Corn is the primary grain used to feed laying hens in southeastern Mexico. However, the majority of this corn is imported from the United States, and its price is subject to fluctuations in the exchange rate between the Mexican peso and the U.S. dollar. These fluctuations increase production costs and contribute to uncertainty among producers regarding the availability of corn on the international market, a situation common in many countries (Abouelezz et al., 2018; Yadav et al., 2019).

An alternative to replace corn in feed for laying hens is the use of cassava (*Manihot esculenta* Crantz). Cassava is native to Latin America, including México (Mohidin *et al.,* 2023). Currently, cassava is cultivated in countries with tropical or subtropical climates in America, Asia, and Africa, and its tubers and leaves can be used as food for animals (Aladi et al., 2017; Odile-Raphaelle et al., 2022). In Mexico, the main cassava-producing states are Tabasco, Veracruz, Oaxaca, Yucatán, and Campeche (González-Valdivia et al., 2023).

The cassava tuber is a high-energy food source rich in carbohydrates, primarily in the form of starch (70-80%), and simple sugars, which can provide a greater amount of metabolizable energy in poultry diets (Akapo et al., 2014; Bakare et al., 2021). The metabolizable energy (ME) content of cassava tubers for poultry has been reported to range between 2,990 and 3,279 kcal/kg, depending on factors such as variety, processing method, and inclusion level in the diet (Olugbemi *et al.,* 2010; Morgan and Choct, 2016; Yadav *et al.,* 2019). The use of cassava tubers with various treatments in poultry, pig, and rabbit feed has been reported (Tonukari et al., 2016; Aladi et al., 2021; Lucena et al., 2023; Bamigboye et al., 2024). However, the use of cassava in the feeding of monogastric animals is limited by its high content of cyanogenic glycosides (Bakare *et al.,* 2021; Chukwukaelo *et al.,* 2023). In this regard, several treatments are available to eliminate cyanogenic glycosides from cassava, including sun drying and oven drying, which are simple, cost-effective, and efficient methods (Bakare et al., 2021; Mohidin et al., 2023). Other alternatives have also been proposed, such as the addition of exogenous enzymes and fermentation using fungi or bacteria. These methods can enhance the nutritional value of cassava, although they are generally more time-consuming and expensive (Khempaka et al., 2018; Ogbuewu et al., 2023; Ogbuewu and Mbajioru, 2023). Among the available methods, thermal treatment is considered the most straightforward and most economical method (Aladi *et al.,* 2021).

Cassava has been reported to be included in broiler chicken diets at levels ranging from 15% to 50%. The inclusion rate largely depends on the processing methods applied to the cassava tubers (Yadav *et al.*, 2019; Lucena et al., 2023; Yang et al., 2024). Lucena *et al.* (2023) reported that including up to 50% sun-dried cassava in broiler chicken diets had no adverse effects on productive performance.

Although recent data on the use of cassava tubers in laying hen diets are limited, several studies support their inclusion at levels ranging from 15% to 30% (Aderemi *et al*., 2012; Khempaka *et al.,* 2018; Ogbuewu and Mbajioru, 2023). Other investigations have evaluated the complete replacement of maize with sun-dried cassava, reporting reduced feed intake and impaired feed conversion efficiency as a result of this substitution strategy (Enyenihi *et al.,* 2019; Kibret *et al*., 2021). Therefore, the present study aimed to evaluate the effects of including up to 40% cassava tuber meal in the diet on egg production and egg quality in laying hens

MATERIALS AND METHODS

Location

The study was conducted at the Instituto Tecnologico de la Zona Maya, located at kilometer 21.5 on the Chetumal-Escarcega highway, in the ejido Juan Sarabia, Quintana Roo, México. The climate of the region is classified as warm-subhumid (AW1). The average annual temperature ranges from 24.5 to 25.8 °C, and the site is situated at an average elevation of 15 meters above sea level (INEGI, 2022).

Ethical statement

The Instituto Tecnológico de la Zona Maya (ITZM) does not have an ethics committee responsible for reviewing projects involving the use of animals. Despite this, the birds used in this study were handled in accordance with the technical specifications outlined in the Mexican Official Standard NOM-062-ZOO-1999, which regulates the care and use of animals under experimental conditions (Diario Oficial de la Federación, 2021). Additionally, the hens were housed in spaces twice the minimum recommended size, with 800 cm² per individual instead of the suggested 400 cm², keeping two birds per cage designed for four.

Animals and management

Ninety Bovans White hens aged 50 weeks were used. The average and standard deviation of the initial live weight were 1.512 ± 0.13 kg. The hens were housed in cages equipped with linear feeders and automatic drinkers to ensure consistent access to feed and water. Before the experimental period, all birds were dewormed using Ectosin® (1 mL per liter of water; Pisa Laboratories®) and supplemented with water soluble vitamins (Carosen®, 1 mL per 5 liters of water; Pisa Laboratories®).

Treatments and experimental management

Fresh green cassava tubers were harvested from the experimental plots of the Instituto Tecnológico de la Zona Maya (ITZM) for the preparation of cassava flour. The tubers were washed and manually chopped with a machete without removing the peel. The chopped material was uniformly spread on aluminium trays and dried in a convection oven at 60°C for 72 hours, or until a constant weight was achieved. The dried tubers were then ground using a hammer mill fitted with a 3 mm sieve. The proximate composition of the resulting cassava flour is presented in Table 1. The cassava flour was stored in sealed plastic bags under dry conditions until it was incorporated into the experimental diets.

Table 1. Nutritional composition of cassava tuber flour.

	Cassava tuber flour
Dry matter (%)	94.50
Organic matter (%)	90.70
Crude Protein (%)	3.20
Crude fibre (%)	7.34

Before the start of the trial, hens underwent a 15-day acclimation period to the experimental diets and management conditions. The experimental phase lasted for 14 weeks.

Feed was offered ad libitum three times daily at 08:00, 12:00, and 16:00 hours. At the end of each week, feed refusals were weighed, and feed intake was calculated as the difference between the amount offered and the amount refused per cage, expressed in grams per hen per day (g/hen/day).

Eggs were collected daily at 09:00, 13:00, and 17:00 hours from each cage. Egg production was recorded and expressed as laying rate (%) every two weeks. Eggs from each cage were counted and weighed using an Ohaus® CS 200 scale to determine average egg weight (g/hen/day). Feed conversion ratio (FCR) was calculated by dividing the total feed intake by the total egg mass produced, and expressed as kilograms of feed per kilogram of egg (kg feed/kg egg).

Experimental diets

Five experimental diets containing 0%, 10%, 20%, 30%, and 40% cassava flour were formulated using soybean meal, corn, vitamin–mineral premixes, synthetic amino acids, and feed additives, as detailed in Table 2. The formulations were based on the nutritional requirements specified in the Bovans White Chicken Feeding Management Guide for laying hens aged 50 to 64 weeks (Hendrix Genetics, 2020). The diets were formulated to contain 2,600 kcal of metabolizable energy (ME), which is 100 kcal below the recommended level, to limit the inclusion of vegetable oil to no more than 3% and to maintain isoenergetic conditions across treatments. Reducing dietary energy may be beneficial under warm climate conditions, as it can help sustain feed intake (Almeida *et al.,* 2012). Following formulation, the diets were stored in sealed plastic containers to preserve feed quality.

Egg quality

Two eggs per cage were collected at weeks 2, 4, 6, 8, 10, 12, and 14 of the experimental periods and individually weighed using a precision balance with a sensitivity of 0.5 g. Egg length and width were measured using a digital calliper. Each egg was then carefully broken, and its contents were placed on a flat plastic surface. The length and width of the albumen were recorded, and albumen height was measured at the centre of the thick albumen, between the edge of the albumen and the yolk membrane, using a digital calliper.

The yolk was carefully separated and weighed. Albumen weight was calculated as the difference between the total egg weight and the combined weight of the yolk and shell. Yolk width and height were also measured using a digital calliper. The shell weight was determined after drying the shell for four hours in a convection oven at 60 °C. Shell thickness was measured at three points (top, middle, and bottom) using a digital calliper, and the average value was calculated.

The proportions of albumen, yolk, and shell were expressed as percentages of total egg weight. Yolk color was assessed using the Roche Yolk Color Fan, which ranges from 1 to 15. Haugh Units were calculated using egg weight and albumen height, following the formula proposed by Eke *et al.* (2013).

Table 2. Experimental diets and calculated analyses.

	Level of cassava tuber flour (%)				
Ingredients (%)	**0**	**10**	**20**	**30**	**40**
Cassava flour	0.00	10.00	20.00	30.00	40.00
Corn	56.60	45.50	33.20	21.38	9.80
Soybean meal	28.90	30.00	31.30	32.60	33.70
Calcium carbonate	9.20	9.10	9.0	8.90	8.80
Vimifos[1]	3.00	3.20	3.3	3.40	3.50
Soybean oil	0.50	1.10	2.10	2.70	3.10
Salt	0.30	0.30	0.30	0.30	0.30
DL-Methionine	0.20	0.22	0.24	0.26	0.28
Flavomycin	0.20	0.20	0.20	0.20	0.20
Mycosorb	0.10	0.10	0.10	0.10	0.10
Yemix	0.06	0.06	0.06	0.06	0.06
L-Lisine HCI	0.09	0.07	0.04	0.02	0.01
Choline chloride 70%[2]	0.05	0.05	0.05	0.05	0.05
Funginat 42	0.05	0.05	0.05	0.05	0.05
Minerals and Vitamins[4]	0.08	0.08	0.08	0.08	0.08
Oxidox Beta	0.01	0.01	0.01	0.01	0.01
Calculated analyses (%)					
Crude protein	17.0	17	17.0	17.0	17.0
Calcium	4.1	4.1	4.1	4.1	4.1
Methionine + Cystine	0.8	0.8	0.8	0.8	0.8
Crude fiber	3.0	3.4	3.9	4.3	4.7
ME (kcal/kg)[4]	2600	2600	2600	2600	2600

[1] 20% Calcium, 20% Phosphorus.
[2] 700g/kg of Choline chloride.
[3] Minerals and vitamins: Mn, 65mg; I, 1mg; Fe, 55mg, Cu, 6mg; Zn, 55mg; Se, 0.3mg; vitamin A, 8000UI; vitamin D, 2500UI; vitamin E, 8UI; vitamin K, 2mg; vitamin B, 0.002mg; riboflavin, 5.5mg; calcium pantothenate 13mg; niacin, 36mg; Choline chloride, 500mg; folic acid, 0.5mg; thiamin, 1mg; pyridoxine, 2.2mg; biotin, 0.05mg.
[4] Metabolizable energy

Economic Efficiency

Economic efficiency was expressed as the return in U.S. dollars per dollar invested. It was calculated as the difference between the economic return per kilogram of eggs produced per hen per day and the average daily feed cost per hen. The economic return was estimated by multiplying the average egg weight per treatment, adjusted for the laying rate, by the market price of eggs (USD 2.50/kg). The daily feed cost per hen was determined by multiplying the average feed intake by the cost per kilogram of feed specific to each treatment. Feed costs were calculated based on current ingredient prices, including a fixed cost of USD 0.10/kg for cassava flour.

Statistical analysis

Five cassava treatments (0%, 10%, 20%, 30% and 40%) were evaluated in the diet of laying hens. There were nine replicates per treatment, and the experimental unit consisted of two hens per cage. The normality of the data distribution was assessed using the Shapiro-Wilk test (SAS, 2010). Data were subjected to analysis of variance using the GLM procedure of the SAS program (SAS, 2010) for a completely randomized design with repeated measures in time (weeks of laying). Mean values of the results were compared using Tukey's test when statistically significant differences were detected ($P < 0.05$).

RESULTS

The results for the productive performance of laying hens fed varying levels of cassava tuber meal are presented in Table 3. The highest feed intake was observed in hens receiving the diet containing 40% cassava ($P<0.05$). The laying percentage, egg weight and feed conversion were not significantly affected by the dietary treatments ($P>0.05$).

None of the traits evaluated in the eggs, albumen and yolk were significantly affected by the level of cassava in the diet ($P>0.05$). However, the color of the yolk tended to be less yellow ($P<0.06$) in the treatments with the highest cassava inclusion levels (Table 4).

Table 3. Means of productive traits of laying hens fed five levels of cassava tuber flour.

	Level of cassava tuber flour (%)						
Traits	0	10	20	30	40	SEM[1]	P value
Feed intake (g/hen/day)	117.1[b]	118.0[b]	117.4[b]	116.1[b]	128.6[a]	0.002	0.004
Laying rate (%)	92.5	91.7	92.9	94.4	92.5	2.351	0.942
Egg weight (g/hen/day)	56.2	54.2	54.8	56.9	56.6	0.001	0.401
Feed conversion (kg feed/kg egg)	2.1	2.2	2.2	2.0	2.3	0.062	0.105

[a, b] Means with equal letters are not statistically different (P<0.05)

[1] SEM = Standard error of the mean.

Table 4. Characteristics of egg quality of hens fed cassava tuber flour.

	Level of cassava tuber flour (%)						
Traits	0	10	20	30	40	SEM[1]	P value
Egg traits							
Length (mm)	57.5	56.9	58.0	57.8	57.7	0.313	0.149
Width (mm)	43.6	43.1	43.7	43.2	43.3	0.187	0.190
Shell thickness (mm)	0.31	0.31	0.32	0.31	0.32	0.004	0.174
Shell weight (g)	5.6	5.5	5.6	5.6	5.7	0.242	0.251
Albumen traits							
Weight (g)	40.8	39.0	40.9	40.6	40.0	0.611	0.152
Heigth (mm)	8.6	8.3	8.5	8.1	8.3	0.151	0.140
Length (mm)	112.1	113.4	113.4	114.4	113.0	0.978	0.585
Width (mm)	83.3	81.1	83.3	86.0	83.3	1.270	0.141
Yolk traits							
Weight (g)	17.1	16.5	16.5	16.5	16.9	0.207	0.153
Heigth (mm)	15.9	15.6	15.9	15.6	15.5	0.158	0.311
Width (mm)	40.8	40.2	41.0	40.5	40.9	0.260	0.210
Yolk color	4.0	4.0	4.0	3.8	3.7	0.099	0.058
Haugh units (%)	92.2	91.2	91.9	89.9	90.2	0.658	0.070

[1] SEM = Standard error of the mean.

Profitability was not affected by replacing corn with cassava. The observed results indicate that up to 82% of the corn in the diet can be replaced with 40% cassava tuber flour without compromising the economic efficiency of egg production (Table 5).

DISCUSSION

The significant increase in feed consumption observed in the diet with 40% cassava tuber disagrees with the results of Kibret *et al.* (2021), who found a decrease in feed consumption in laying hens when increasing cassava tuber content in the feed. In this work, the increase in feed consumption resulting from 40% cassava treatment can be attributed to the higher fibre content in the feed (Table 2). It should be noted that cassava with peel was used in this work, resulting in an increase in fibre content in the feed with increasing cassava content. The increase in fibre decreases the digestibility and availability of energy in the diet, leading to an increase in feed consumption by the hens to meet their energy requirements (Abdollahi *et al.,* 2019; Whiting *et al.,* 2019; Diaz-Echeverria *et al.,* 2023). The increase in feed consumption due to the

Table 5. Profitability of laying hens fed diets containing cassava tuber flour.

	Level of cassava tuber flour (%)				
Traits	0	10	20	30	40
Feed consumption (g/day)	117.1[b]	118.0[b]	117.4[b]	116.1[b]	128.6[a]
Price per kg of feed (dollar)	0.39	0.40	0.40	0.39	0.38
Cost of feed consumed (dollar)	0.05	0.05	0.05	0.05	0.05
Egg produced/hen/day (g)[1]	52.0	49.7	50.9	53.7	52.4
Price per kg of egg (dollar)	2.50	2.50	2.50	2.50	2.50
Income per eggs sold	0.13	0.12	0.13	0.13	0.13
Economic efficiency[2]	2.6	2.4	2.6	2.6	2.6

[1] Calculated as average egg weight, adjusted by the percentage of lay per treatment.

[2] The economic efficiency is expressed as the dollars returned for each dollar invested.

increase in fibre was particularly observed in laying hens fed diets containing tree fodder (Abou-Elezz *et al.,* 2012; Diaz-Echeverria *et al.,* 2023). It is possible that the metabolizable energy (ME) value assigned to cassava in this study was overestimated. Olugbemi *et al*. (2010) reported that cassava can contain up to 3,279 kcal ME/kg. However, in this study, cassava tubers with peel were used, which have higher fibre content compared to peeled cassava. A value of 3,000 kcal ME/kg was used for diet formulation, similar to the 2,990 kcal ME/kg reported by Yadav *et al*. (2019). Given the higher fibre content of the cassava with peel, it is likely that its actual ME value was lower than 3,000 kcal/kg. These factors (the fibre content and the potential overestimation of cassava's energy value) may explain the increased feed intake observed in hens fed the diet containing 40% cassava.

No significant effect of cassava content in the diet was observed on any of the egg traits evaluated. The results of egg production and egg quality were comparable between the diets with cassava tuber flour and the control diet. Inclusion of up to 40% cassava in the diet replaced 82% of the corn used in the control diet. These results agree with those reported by Kibret *et al.* (2021) and Enyenihi *et al.* (2009), who successfully replaced 100% of corn with cassava in laying hens' diets without affecting albumen and yolk characteristics. The findings of the present study exceed those of previous research recommending a maximum inclusion of 25 to 30% cassava in laying hens' diets (Aderemi *et al.,* 2012; Khempaka *et al.,* 2018; Ogbuewu *et al.,* 2023). It is important to note that some of these studies did not use cassava tubers exclusively, but rather a mixture of tubers, leaves and stems (Adermi *et al.,* 2012).

One of the main limitations to the use of cassava in laying hen diets is its content of cyanogenic glycosides (Ogbuewu and Mbajiorgu, 2023). In the present study, no toxic effects of these compounds on feed intake or egg production were observed (Bakare et al., 2021; Mohidin et al., 2023). The chopping and oven-drying process applied to cassava tubers in this study appears to have been effective in reducing cyanogenic glycoside content, as reported by several authors (Olafadehan et al., 2012; Bakare et al., 2021; Lucena et al., 2023). For instance, sun drying can reduce the cyanogenic glucosides in cassava by 77 to 93% (Enyenihi *et al.,* 2009; Olafadehan *et al.,* 2012).

Although there was no statistically significant effect ($P>0.05$) of the treatments on egg yolk color, a tendency to decrease color was observed in the 40% cassava treatment ($P<0.06$). Corn is rich in pigments such as xanthophylls and carotenes, whereas cassava contains minimal amounts of these compounds (Prommetta *et al.,* 2020; Ortiz *et al.,* 2021). Therefore, the color of the yolk decreased when corn was replaced by cassava in this work, even when a yellow commercial pigment was added to the feed. It would be advisable to adjust the content of commercial pigments in the diet for laying hens when corn is replaced by cassava.

The inclusion of cassava tuber flour in laying hen diets did not affect the economic efficiency of egg production in this study, as egg production remained unchanged, and feed costs were not significantly reduced. Based on the results of this study, replacing up to 82% of corn with 40% cassava suggests that local egg producers could reduce their dependence on imported corn and be less economically affected by fluctuations in international corn prices and exchange rates (Odille-Raphaelle *et al.,* 2022; Ogbuewu *et al.,* 2023; Ogbuewu and Mbajiorgu, 2023). Additionally, national cassava producers could benefit from increased demand, which may lead to expanded production, job creation, and greater involvement of local farmers in cassava cultivation.

CONCLUSIONS

The results of this demonstrate that up to 82% of the corn in laying hen diets can be replaced with 40% unpeeled cassava tuber flour, without compromising productive performance, egg quality or the economic efficiency of egg production.

Compliance with ethical standards. The birds used in this study were handled in accordance with the technical specifications outlined in the Mexican Official Standard NOM-062-ZOO-1999, which regulates the care and use of animals under experimental conditions (Diario Oficial de la Federación, 2021).

Funding. The authors did not receive funding.

Conflict of interest. The authors declare that they have no competing interests to declare.

Data availability. Data is available upon reasonable request to the corresponding author.

Author contribution statement (CRediT). V.F. Díaz-Echeverría – Conceptualization, Methodology, Investigation, and Funding acquisition**. I.A. May-Avila –** Conceptualization, Methodology, Writing-original draft. **J.C. Segura-Correa –** Methodology, Formal analysis, Writing- review and editing. **R.H. Santos-Ricalde** – Methodology, Writing- review and editing.

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