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GANADERÍA

CARACTERIZACIÓN FENOTÍPICA Y COMPORTAMIENTO PRODUCTIVO DE POLLOS DE TRASPATIO EN EL ESTADO DE CAMPECHE, MÉXICO

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T E S I S

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CARACTERIZACIÓN FENOTÍPICA Y COMPORTAMIENTO PRODUCTIVO DE POLLOS DE TRASPATIO EN EL ESTADO DE CAMPECHE, MÉXICO

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RESUMEN

Se realizaron dos estudios para 1) caracterizar el sistema de producción de pollos de traspatio y 2) comparar los modelos de crecimiento de Gompertz, Logístico, Richards y Von Bertalanffy para determinar el mejor modelo que se ajuste a los datos de los pollos de traspatio (PT) en Campeche, México. En el estudio 1: 260 encuestas fueron aplicadas personalmente. Se encontró que las amas de casa realizan las actividades de producción del traspatio. El tamaño de la parvada fue de 24.4 ± 1.3 aves por hogar. Los pollos alcanzan la madurez sexual alrededor de los seis meses de edad. El número de huevos/gallina/año y el peso de huevo fue de 45.8 ± 1.6 y 54.9 ± 5.0 g, respectivamente. Los sistemas de producción utilizados son el confinado y semiconfinado. Los pollos reciben maíz, mientras que los pollitos son alimentados con alimento comercial y maíz. Sólo los pollos en pastoreo son suplementados con maíz y salvado de trigo. Durante la temporada de lluvias, la gripe y las enfermedades diarreicas son más frecuentes. El tamaño corporal es el rasgo principal para adquirir/seleccionar reproductores dentro/fuera de la parvada. La escasez de alimentos, las enfermedades, los depredadores y la falta de asistencia técnica fueron las principales limitaciones para la producción de pollos de traspatio. En el estudio 2; 347 PT se pesaron individualmente desde la eclosión hasta los 177 días de edad. El coeficiente de determinación (R^2) y los criterios de información Akaike (AIC) y Bayesiano (BIC) se utilizaron para comparar la bondad de ajuste de los modelos. El modelo Von Bertalanffy (R^2: 0.9382; 0.9415; AIC: 2,224.1; 2,424.8; BIC: 2,233.5; 2,434.3, para hembras y machos, respectivamente) fue el mejor modelo que explicó el crecimiento de las aves. Las hembras alcanzaron la edad de máximo crecimiento más rápido que los machos. El peso asintótico fue mayor en los machos (3,011.3 g) que en las hembras (2,011.6 g). El peso corporal al punto de inflexión fue de 892.2 g a los 64.3 días de edad para los machos y de 596.0 g a 54.4 días para las hembras. En conclusión: 1) la producción de pollos de traspatio proporciona una fuente disponible de proteína animal e ingreso en efectivo para los hogares y 2) el mejor ajuste de los datos se obtuvo con el modelo Von Bertalanffy. Se pretende que esta información sirva de base para la utilización de los recursos genéticos avícolas de traspatio.

Palabras clave: pollos de traspatio, caracterización, curvas de crecimiento, modelos no lineales, Campeche, México

PHENOTYPIC CHARACTERIZATION AND PRODUCTIVE PERFORMANCE OF BACKYARD CHICKENS IN CAMPECHE STATE, MEXICO

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ABSTRACT

Two studies were carried out: 1) to characterize the backyard chicken production system and 2) to compare the Gompertz, Logistic, Richards and Von Bertalanffy growth models for determining the best model that fits the data of the local chickens (LC) in Campeche, Mexico. In study 1: 260 surveys were administered in person. It was found that housewives mainly undertake backyard production activities. Flock size was 24.4 ± 1.3 birds per household. Chickens reach sexual maturity at around six months of age. The number of egg/hen/year and egg weight were 45.8 ± 1.6 and 54.9 ± 5.0 g, respectively. Confined and semi-confined production systems are used. Chickens receive corn, whereas chicks are fed with commercial feed and corn. Only scavenging chickens are supplemented with corn and wheat bran. During the rainy season, flu and diarrheal diseases are more frequently observed. Body size is the main trait for acquiring/selecting breeders within/outside the flock. Feed shortages, diseases, predators, and lack of technical assistance services were the major constraints for LC backyard production. In study 2; 347 LC were individually weighed from hatching until 177 days of age. The determination coefficient (R^2), Akaike' (AIC) and Bayesian information criteria (BIC) were used to compare the goodness of fit for models. The Von Bertalanffy (R^2: 0.9382; 0.9415; AIC: 2,224.1; 2,424.8; BIC: 2,233.5; 2,434.3, for females and males, respectively) was the best model explaining the growth of birds. Females reached age of maximum growth faster than males. The asymptotic weight was higher in males (3,011.3 g) than in females (2,011.6 g). Body weight at inflection point was 892.2 g at 64.3 days of age for males and 596.0 g at 54.4 days for females. In conclusion: 1) backyard chicken production based on LC provides a readily available source of animal protein and cash income for households and 2) the best fit of the data was obtained with the Von Bertalanffy growth model. This information is intended to serve as the basis for utilizing local poultry genetic resources.

Key word: backyard chickens, characterization, growth curves, non-linear models, Campeche, Mexico.

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INTRODUCCIÓN GENERAL

La avicultura de traspatio es una actividad que se practica en las zonas rurales de México, esta actividad genera alimentos (carne y huevo) e ingreso económico para la familia y es realizada por amas de casa y niños (Cuca-García et al., 2015; Camacho-Escobar et al., 2006). Esta actividad se basa en la crianza de pollos criollos, es decir, aves que presumiblemente descienden de aquellas traídas a México por los españoles en el siglo XVI (Segura-Correa et al., 2007; Strillacci et al., 2018). Estas aves han estado bajo selección natural durante casi cinco siglos provocada por factores como la temperatura, humedad ambiental, escasez de alimento y enfermedades o parásitos, entre otros, (Henson, 1992). De esta manera, se cree que estas aves están adaptadas a las condiciones climáticas locales y por ello se consideran un valioso recurso genético (Segura-Correa 2007). Los pollos de traspatio pueden sobrevivir y producir carne y huevo en ambientes hostiles, alimentación y condiciones sanitarias deficientes (Dessie et al., 2011; Padhi, 2016), lo que se refleja en un bajo comportamiento productivo en comparación con gallinas comerciales (Segura-Correa et al., 2004; Itza-Ortiz et al., 2016). Por otra parte, el peso corporal de los pollos de traspatio es una de las características importantes para las familias rurales (Osei-Amponsah et al., 2013). El crecimiento de estas aves se ha evaluado mediante funciones matemáticas o curvas de crecimiento que dan como resultado parámetros que son biológicamente interpretables (Tzeng y Becker, 1981; Aggrey, 2002; Yang, 2006). En los países en vías de desarrollo, algunos investigadores han estudiado el crecimiento de los pollos de traspatio utilizando los modelos Gompertz, Logístico, Richards (Norris et al., 2007; Olawoyin et al., 2007; Magothe et al., 2010; Rizzi et al., 2013 y Osei-Amponsah et al., 2014) y Von Bertalanffy (Yang et al., 2006; Ngeno et al., 2010; Zhao et al., 2015). Sin embargo, las investigaciones sobre las prácticas de crianza y el comportamiento productivo de los pollos de traspatio en México ha sido abordado por un número reducido de investigadores

(Prado-González et al., 2003; Candelaria-Martínez et al., 2016; Flota-Bañuelos et al., 2016). En base a lo anteriormente expuesto, en la presente investigación se caracterizó el sistema de producción y el patrón de crecimiento de los pollos de traspatio como un paso previo en el desarrollo de estrategias de mejora genética.

Objetivo general

Describir el sistema de producción y el patrón crecimiento de los pollos de traspatio del estado de Campeche, México.

Objetivos específicos

1. Caracterizar el sistema de producción de los pollos de traspatio en el estado de Campeche, México.
2. Describir el patrón de crecimiento de los pollos de traspatio con modelos no lineales y determinar el que mejor se ajuste.

Hipótesis del objetivo específico 2

De los siguientes modelos de crecimiento Gompertz-Laird, Richards, Logístico y Von Bertalanffy, al menos uno se ajustará al patrón de crecimiento de los pollos de traspatio del estado de Campeche, México.

REVISIÓN DE LITERATURA

Traspatio

El traspatio es definido como un agroecosistema adjunto a las viviendas donde por acción humana se han concentrado diversos componentes e interacciones que favorecen una rica biodiversidad, tiene un rol relevante en la alimentación de las familias rurales, además contribuyen a la conservación y reproducción de especies animales y vegetales (González-Ortiz et al., 2014; Duché-García et al., 2017). Adicionalmente, Jiménez-Osorio (1999) menciona que los traspatios son diversos en cantidad y variedad de especies, y presentan características idóneas para ser considerados como un lugar de conservación de germoplasma *in situ*.

El traspatio es conocido con diferentes nombres: en la península de Yucatán es llamado solar (Jiménez-Osorio, et al., 1999; Flota-Bañuelos et al., 2016), mientras que en Tabasco las familias rurales le llaman patio y en Michoacán es conocido como huerta (Mariaca-Méndez, 2012).

El traspatio es parte integral de la alimentación local en los países en desarrollo (Hashini-Galhena et al., 2013). Los beneficios que aporta el traspatio son: mejora de la seguridad alimentaria y nutricional, mejora la salud familiar, genera ingresos económicos y preserva el conocimiento y la cultura indígena (Mitchell and Hanstad, 2004).

Componente animal del traspatio

La crianza de diferentes especies animales en el traspatio está influenciada por la situación económica, interés del agricultor y comercialización de los productos (Sunwar et al., 2006). La producción pecuaria en el traspatio es un sistema caracterizado por la crianza de aves, cerdos, caprinos, ovinos y bovinos (Gutiérrez-Triay et al., 2007), sin embargo, los caballos, burros y bueyes son utilizados en la producción agrícola como tracción animal, transporte de cosechas y de personas (Mendoza et al., 2014).

La importancia del componente pecuario para las familias rurales radica en obtener proteína de buena calidad como la carne, leche y huevo y productos derivados como el queso; además, se generan recursos económicos por la comercialización de dichos productos (López-González, 2012).

La diversidad de animales presentes en el traspatio ha sido reportada por varios investigadores, Chablé-Pascual et al. (2015) encontraron que las gallinas, pavos y patos son los animales que predominan, no obstante, se puede encontrar perros los cuales son utilizados como guardianes de la casa. Los animales que crían las familias de Cholula, Puebla son gallinas y guajolotes (53.0%), ovinos/caprinos (24.0%), cerdos (9.0%), burros/caballos (8.0%), y vacas (6.0%) (López-González et al., 2013). Flota-Bañuelos et al. (2016) reportaron que el 62.5% de las familias rurales crían animales en sus traspatios; entre los cuales se encontraron gallinas, pavos, cerdos, patos, ovinos, bovinos y peces. De lo anterior, las aves de corral, en especial las gallinas son los animales que predominan en los traspatios de las familias rurales de México, ya que las personas prefieren la crianza de estas aves debido a su prolificidad, velocidad de madurez sexual, rusticidad, aporte de proteína de alto valor nutritivo y por ser una especie que aprovecha al máximo la mano de obra familiar (Camacho-Escobar et al., 2006).

Avicultura de traspatio

La avicultura comprende la crianza de aves de corral como gallinas, pavos, patos y codornices, entre otras (Itza-Ortiz et al., 2016). La avicultura de traspatio está presente en 85.0% de las unidades de producción (Camacho-Escobar et al., 2006), y de acuerdo con Lastra et al. (1998) representa hasta el 10.0% de la producción avícola nacional. En México, existen tres sistemas de producción: intensivo, semi-intensivo y el de traspatio o rural, los cuales están diferenciados en base al esquema tecnológico y objetivos de producción que utilizan (Alonso-Pesado et al., 2009).

La avicultura de traspatio es una actividad pecuaria que se realiza en las zonas rurales de México; se lleva a cabo en los patios de los hogares y consiste en criar un pequeño grupo de aves como gallinas o guajolotes (Cuca-García et al., 2015). Las aves son alimentadas con granos producidos por los agricultores, en ocaciones con desperdicios de la unidad familiar y lo que las aves colectan durante el pastoreo (Juárez-Caratachea y Ortiz-Alvarado, 2001). Este sistema de producción no implica elevados gastos de inversión economica, las instalaciones son fabricadas con materiales de cada región como: troncos, piedras y palmas, entre otros, sin embargo, en algunos taspatios las aves permanecen sueltas y duermen a la intemperie quedando expuestas a la severidad del clima y a los depredadores (Camacho-Escobar et al., 2006; Itza-Ortiz et al., 2016).

Pollos de traspatio

Los pollos criados en el traspatio representan el material genético de distintas razas, estas aves han estado sometidas a la selección natural provocada por factores ambientales, disponibilidad de alimentos y enfermedades, entre otros. Estas aves se han adaptado a las condiciones de crianza en libre pastoreo, lo que les confiere una amplia variabilidad genética, razón por la cual constituyen un auténtico reservorio genético (Henson, 1992; Albalat-Botana, 2011).

En la mayoría de los traspatios, los pollos criados por las familias rurales provienen de la incubación de huevos de las gallinas criollas que se encuentran en las comunidades rurales, sin embargo, existe la introducción de razas de doble propósito como la Rhode Island Red y Plymounth Rock Barrada que son distribuidas a través de programas de gobierno como apoyo a las familias. Otro forma de adquisición de las aves es por medio de la compra de pollitas o gallinas en tiendas veterinarias (Centeno-Bautista et al., 2007).

En las poblaciones de pollos de traspatio existen genes de apariencia fenotípica que les confieren adaptabilidad, como el plumaje rizado, plumaje sedoso, cuello desnudo y scalers (presencia de escamas en los folículos en lugar de plumas). Estos genes ayudan a desarrollar procesos fisiológicos como la disipación de calor corporal del ave en condiciones de elevada temperatura ambiental. (Juárez et al., 2000; Daghir, 2008).

Por medio de los programas gubernamentales se ha sustituido los genotipos avícolas criollos por aves mejoradas. Por lo tanto, se presenta la pérdida de material genético de aves adaptadas a ambientes locales dentro del territorio nacional (Juárez et al., 2000). Nigussie et al. (2010) reportaron que las aves mejoradas introducidas a los traspatios son susceptibles a enfermedades, estrés por calor y no tiene la capacidad para escapar de los depredadores. Además, mencionan que la incubabilidad de los huevos de las aves mejoradas es inferior a los huevos de aves criollas.

Prácticas de crianza de los pollos de traspatio

Alimentación

Los pollos de traspatio sobreviven con lo que consumen durante el pastoreo, la principal fuente de alimentación son insectos, residuos de cultivos y de cocina (Bhuiyan et al., 2005). Por otra parte, la suplementación de las aves es una práctica que se realiza para aumentar la ganancia de peso y en consecuencia la producción de carne o huevo (Addisu et al., 2013). En Oaxaca, México el 45.8% de las familias suplementa a las aves con alimento balanceado (Viveros-Hernández et al., 2016). De manera similar, las familias del estado de Puebla, México alimentan a las aves adultas con maíz y masa, mientras que a los pollitos les ofrecen alimento comercial. El consumo promedio reportado es de 100 g de maíz en gallinas y 30 g de alimento comercial en los pollitos. Comúnmente, el 82.0% de las familias proporciona el alimento en el piso, el 11.8% usa contenedores reciclados y solo el 5.9% en comederos de tolva (Centeno-Bautista et al., 2007).

En el estado de Campeche, México las aves son alimentadas con maíz (91.0%) y plantas que las aves encuentran en el traspatio (Candelaria-Martínez et al., 2016).

Tadelle y Olgle (1996) mencionaron que la alimentación de las gallinas de traspatio es deficiente en proteína, energía y calcio, ya que al incorporar estos nutrientes en la alimentación de estas aves observaron un aumento en la producción y calidad del huevo.

Instalaciones y equipo

En los traspatios de México, los gallineros están construidos con materiales locales, por lo regular, las gallinas permanecen encerradas durante la noche y en el día salen a pastar (Gutiérrez-Triay et al., 2007). Los materiales más comunes empleados para la construcción de los gallineros incluyen: lámina de cartón (59.6%), palma de huano (*Sabal japa*, 23.3%) y lamina de zinc (13.0%). Las paredes son de malla de alambre (28.5%), palos (27.5%) y piedras (6.7%) y el piso de tierra (94.3%) (Gutiérrez-Ruiz et al., 2012). Como comederos y bebederos se utilizan recipientes de plástico y ollas de desecho (Gutiérrez-Triay et al., 2007).

Por otro lado, Juárez-Caratachea et al. (2008) encontraron que en el estado de Michoacán, México las familias prefieren que las aves duerman y se protejan de las inclemencias del clima en los árboles; el alimento es proporcionado en el piso y el agua la obtienen de los charcos o de los bebederos de otros animales que se encuentran en el traspatio.

Enfermedades

El sistema de producción de traspatio se caracteriza por una alta mortalidad de pollitos durante las primeras dos semanas de vida, causada principalmente por enfermedades y depredadores (Aberra y Tegene, 2011). Las enfermedades que afectan la avicultura de traspatio basado en la descripción de los signos que observan los productores en las aves son: Newcastle, influenza aviar, pasteurelosis y viruela aviar (Camacho-Escobar et al., 2008).

La mortalidad de las gallinas es una de las causas por la cual se reduce el tamaño de la parvada, Vargas-López et al. (2005) mencionaron que en promedio se pierden cinco animales por año a causa de enfermedades, sin embargo, cuando se presenta la enfermedad conocida por las familias como "peste" (coccidiosis, Newcastle, cólera o bronquitis) la mortalidad es del 100%.

Respecto al manejo sanitario, se ha reportado que solo el 13.3% de las familias vacunan sus aves y el 49.1% aplican algún medicamento casero para curar sus pollos (Gutiérrez-Triay et al., 2007).

Objetivos de crianza y prácticas de selección de los pollos de traspatio

En México, la producción de huevo y carne en el sistema de traspatio es destinada para el consumo (85.9%), la venta (11.3%) y obsequio (2.8%) (Camacho-Escobar et al., 2006). En Samaná, República de Colombia el propósito de criar las gallinas es la producción de huevo para consumo (52.0%), incubación (17.0%) y venta (31.0%) (Tovar-Paredes et al., 2015).

La reproducción de las gallinas en las comunidades rurales se realiza en completo descontrol y el reemplazo de las aves se hace a través de la obtención de animales mediante incubación natural (Nigussie et al., 2010). En un estudio realizado por Sánchez-Sánchez y Torres-Rivera (2014) en Huatusco, Veracruz encontraron que el 34.0% de las familias selecciona sus gallos en base a el tamaño corporal y libido; mientras que el 29.0% selecciona gallinas en relación al tamaño corporal, habilidad materna y número de huevos por cloquez. De acuerdo con Lázaro et al. (2012) las familias seleccionan sus gallinas basándose en el color del plumaje, ya que algunos productores prefieren gallinas que tengan combinación de colores en su plumaje. En relación a las características productivas, las personas seleccionan las aves por la producción de huevo y tamaño corporal.

Crecimiento animal

El crecimiento es el aumento de tamaño corporal por unidad de tiempo o la relación entre el peso corporal y la edad (Schulze et al., 2001; Lawrence y Fowler, 2002; Al-Samarai, 2015). Esta característica representa un aspecto económico importante en la producción avícola y está influenciado por la genética y el ambiente (Selvaggi et al., 2015). El crecimiento, desde la etapa embrionaria hasta la edad adulta, puede ser explicado matemáticamente mediante modelos de crecimiento (modelos de regresión no lineal) que tienen parámetros con significado biológico (Fitzhugh, 1976). Estos modelos permiten describir el aumento de peso, el peso a la madurez, la tasa de maduración, la relación crecimiento-edad, predecir la edad óptima de sacrificio y estimar los requerimientos alimenticios diarios en los animales (Teleken, et al. 2017). Además, permite a los productores estimar el peso de los animales a una edad específica y detectar la etapa asociada con la reducción en la tasa de crecimiento (Yakupoglu y Atil, 2001; Al-Samarai, 2015).

Modelos utilizados para describir el crecimiento de las aves de corral

Los modelos de regresión no lineal ampliamente utilizados para modelar el crecimiento de las aves de corral son: Gompertz, Logistíco, Von Bertalanffy y Richards (Cuadro 1) (Narinc et al., 2010; Dos Santos et al., 2014; Narinc et al., 2017). Sin embargo, existe discrepancia acerca de cuál de estos modelos es el más apropiado para describir el crecimiento de las aves (Dos Santos et al., 2014). Estas diferencias pueden deberse a un gran número de razones; por ejemplo, la raza o estructura de la población, sexo de las aves, manejo de la alimentación, condiciones ambientales, muestreo y métodos estadísticos. Las curvas de crecimiento en aves poseen las siguientes características: 1) una fase acelerada de crecimiento desde la eclosión, 2) un punto de inflexión en el que la tasa de crecimiento es máxima, 3) una fase de desaceleración de la tasa de crecimiento y 4) un valor límite de peso maduro (Selvaggi et al., 2015).

El modelo de Gompertz supone que el crecimiento es proporcional al peso corporal y que la tasa de crecimiento decae exponencialmente con el tiempo. La ecuación logística supone que el crecimiento aumenta a una tasa proporcional a la cantidad de nutrientes y considera que el crecimiento es irreversible. La ecuación de Richards es un modelo de cuatro parámetros basado en una construcción más empírica con un parámetro de forma que no tiene significado biológico claro.

La razón por la que el modelo de Richards es atractivo para el modelado de curvas de crecimiento es su punto de inflexión variable en proporción al peso asintótico (Selvaggi et al., 2015).

Cuadro 1. Modelos utilizados para modelar el crecimiento en aves de corral.

Modelo	**Ecuación**
Gompertz	$Y_t = \beta_0 . e^{-\beta_1 e^{-\beta_2 t}}$
Logistic	$Y_t = \beta_0 \left(1 + \beta_1 . e^{-\beta_2 t}\right)^{-1}$
Richards	$Y_t = \beta_0 \left(1 + \beta_1 . e^{-\beta_2 t}\right)^{\beta_3}$
Von Bertalanffy	$Y_t = \beta_0 \left(1 - \beta_1 . e^{-\beta_2 t}\right)^{3}$

En los modelos, 't' denota tiempo, 'Y' peso, 'β_0' el peso corporal máximo que se supone que el animal puede alcanzar, ' β_1' la constante biológica sobre la forma de la curva, ' β_2' la constante biológica sobre la tasa de crecimiento y ' β_3' el parámetro de forma (Narinc et al., 2010; Narinc et al., 2017).

Criterios de bondad de ajuste para elegir el mejor modelo de crecimiento

Existen varios criterios utilizados para determinar la bondad del ajuste.

- Coeficiente de determinación, R^2 = 1 - (SSE / SST), donde SSE es la suma de cuadrados del error y SST la suma de cuadrados total.
- Coeficiente de determinación ajustado, R^2 adj. = R^2 - ((k - 1 / n - k) (1 - R^2)), donde n es el número de observaciones y k el número de parámetros.
- Cuadrado medio del error, MSE = SSE / (n - k), donde n es el número de observaciones, SSE es la suma de cuadrados del error y k el número de parámetros.
- Criterio de información de Akaike, AIC = n.ln (SSE / n) + 2k, donde n es el número de observaciones, SSE es la suma de cuadrados del error y k el número de parámetros.

- Criterio de información bayesiano de Schwarz, BIC = n.ln (SSE / n) + k.ln (n), donde n es el número de observaciones, SSE es la suma de cuadrados del error y k el número de parámetros (Narinc et al., 2017; Kaplan y Gürcan, 2018).

Siendo el coeficiente de determinación (R^2) y el coeficiente de determinación ajustado (R^2 adj.) los más comunes que se utilizan para comparar los rendimientos de los modelos de crecimiento (Narinc et al., 2010).

Los parámetros estimados por los modelos de crecimiento podrían incluirse en programas de mejoramiento genético, según lo informado por Barbato (1991) y Mignon-Grasteau et al. (1999) quienes mencionan que los parámetros muestran valores medio-altos de heredabilidad.

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CHAPTER I. CHARACTERIZATION OF THE BACKYARD CHICKEN PRODUCTION SYSTEM IN MEXICO

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1.1. ABSTRACT

Backyard chicken production is an activity that bolsters household income in rural Mexico. This system consists of raising local chickens (LC) for meat and egg production. The aim of this study was to characterize the backyard chicken production system in Mexico, as the basis of a program for utilizing local poultry genetic resources in Campeche State, Mexico. A total of 260 surveys were administered in person. The results showed that housewives mainly undertake backyard production activities. Farmers have, on average, 0.20 ± 0.1 hectares for raising LC. Flock size was 24.4 ± 1.3 birds per household. Chickens reach sexual maturity at around six months of age. The number of egg/hen/year and egg weight were 45.8 ± 1.6 and 54.9 ± 5.0 g, respectively. Mainly confined and semi-confined production systems are used. Farmers fed chickens with corn, whereas chicks were fed with commercial feed and corn. Only scavenging chickens were supplemented with corn and wheat bran. During the rainy season, flu and diarrheal diseases are more frequently observed. Body size is the main trait for acquiring/selecting breeders within/outside the flock. Selection of eggs for incubation is based on size and freshness. Brooding season is from December to June. Families consume LC meat 3.5 ± 2.9 times a month and 17.0 ± 1.0 eggs a week. Most LC are sold as live chicken with price determined by BW. Farmers sell 1.6 ± 0.2 birds per month and 7.6 ± 0.7 eggs per week to get $8.99 ± 0.93 and $3.82 ± 0.33 USD, respectively. Feed shortages, diseases, predators, and lack of technical assistance services were the major constraints for LC backyard production. In conclusion, backyard chicken production based on LC provides a readily available source of animal protein and cash income for households in Campeche State, Mexico.

For this reason, it is necessary to create a program for the raising of local poultry genetic resources in this State.

Keywords: Backyard local chicken, characterization, production system, ecoregion, Mexico

1.2. INTRODUCTION

Backyard poultry farming is an important activity in the rural zones of Mexico; this activity is considered an additional source of household income and is carried out primarily by housewives, children and senior citizens (Cuca-García et al., 2015). This animal production system is based on local chickens (**LC**), that is, birds that presumably descend from those brought to Mexico by the Spaniards in the XV century (Valadez, 2003). Local chickens provide household livelihood security, animal protein and economic income (McAinsh et al., 2004; Padhi, 2016). It has been argued that LC are able to survive and produce meat and eggs under harsh environments, poor nutrition profiles and deficient sanitary conditions (Dessie et al., 2011; Padhi, 2016). However, the productive performance of these birds is low (Okeno et al., 2012). Almost half of the population in Campeche State, Mexico, lives in poverty and it is estimated that 25.0% are located in rural areas (INEGI, 2010; CONEVAL, 2016). The characteristics of the backyard poultry system could have variations among regions within the State. In fact, there is limited information about LC-raising practices in this State of Mexico, and this issue has been addressed by a small number of researchers (Candelaria-Martínez et al., 2016; Flota-Bañuelos et al., 2016). The present investigation is an effort to characterize this animal production system as a step forward in the development of improvement strategies, including for breeding and genetic purposes. These strategies could lead to higher LC productivity, which in turn could improve the quality of life of the rural population in Campeche State, Mexico. Thus, the aim of this study was to characterize the backyard chicken production system in Campeche State, Mexico, in terms of characteristics and constraints. Specific areas covered include source of chickens, housing conditions for birds, management and feeding, health, reproduction, and use and marketing of LC. This information is intended to serve as the basis for the development of a program aimed at improving local poultry genetic resources.

1.3. MATERIALS AND METHODS

Study Sites

This study was conducted in Campeche State, located in southeastern Mexico on the Yucatan Peninsula. In order to carry out the sampling process, the ecological and biogeographical regionalization reported by CONABIO (2007) was used. Four ecoregions were sampled: wetlands of northern Yucatan (**WNY**), central plain of Yucatan (**CPY**), low hills of southern Yucatan (**LHSY**), and wetlands of the southern Gulf of Mexico (**WSGM**). Most of the territory (99.7%) has a warm humid to subhumid climate. Temperature ranges from 18 to 30°C; abundant rains occur during the summer (June to September), with total annual precipitation ranging from 1,200 to 2,000 mm. This study was conducted from June to December 2016.

Sampling Procedure

To determine sample size in each ecoregion, the following methodology described by FAO (2012) for phenotypic characterization of animal genetic resources was used:

$$n=\frac{\left(\frac{z}{m}\right)^{2}p\left(1-p\right)}{1+\frac{\left(\frac{z}{m}\right)^{2}p\left(1-p\right)}{N}}$$

Where *z* is the z value (1.95 for 95% confidence level); *m* is the margin of error (0.05); *p* is the estimated value for the proportion of the sample that will respond in a given way to a survey question (0.50); *n* is the sample size; and *N* is population size [number of dwellings inhabited as reported by SEDESOL (2015)]. Using this criterion, 29, 153, 24 and 54 households were selected from the WNY, CPY, LHSY and WSGM ecoregions, respectively. In each ecoregion, three communities were randomly selected. Within each selected community, a non-probabilistic snowball sampling method (Goodman, 1961) was used to identify farmers that raise LC.

Survey Application

A total of 260 surveys were administered in the four ecoregions. A well-structured survey was designed with closed questions to collect information on: farmers and their households, flock structure and productive performance, source and housing conditions for LC, feeding and sanitary management, breeding methods and selection criterion, consumption, marketing of LC, and constraints when these birds are raised. The purpose of the interview was fully explained to each respondent, and subsequently the survey was applied.

Statistical Analysis

Frequency and descriptive statistics were used to statistically analyze the data with the PROC FREQ and PROC MEANS of SAS Institute Inc. (version 9.3, 2011), respectively. The effect of the ecoregion on the different variables was estimated using the model below:

$$y_{ij} = \mu + eco_i + \varepsilon_{ij}$$

Where y_{ij} is the dependent variable, μ the overall population mean, eco_i the ecoregion effect (i= WNY, CPY, LHSY and WSGM) and ε_{ij} the random residual effect.

1.4. RESULTS

Farmer and Farm Characteristics

Backyard poultry production activities were mainly carried out by housewives (81.4%). The majority of the farmers had a formal education (82.5%), whereas only 17.5% were illiterate, and about half of them speak a Mayan dialect (45.8%). Farmers' age was different ($P < 0.01$) among ecoregions; average age was 46.3 ± 0.9 years with a range from 44.2 to 54.3 years. Mean family size was 4.5 ± 0.1 persons, and farm size was 0.2 ± 0.1 hectares where the most important livestock species were LC, followed by turkeys and ducks. The number of livestock species was different among ecoregions ($P < 0.01$); in the LHSY ecoregion a greater number of sheep was found compared to the other ones (Table 1). Additionally, the main reason for raising LC reported by farmers was to obtain a source of food (83.1%), followed by selling their surplus products (chickens and eggs) for cash (14.2%). Only farmers in the WNY and WSGM ecoregions raise LC as ornamental birds (2.7%) (data not shown in tables).

Table 1.1. Characteristics of local chicken farmers and their farms

Variables	Ecoregions				Overall mean	Sig. (*P*-value)
	WNY (n = 29)	CPY (n = 153)	LHSY (n = 24)	WSGM (n = 54)		
Farmers' characteristics						
Sex of respondent (%)						
Male	10.3	9.8	29.2	18.5	16.9	
Female	89.7	90.2	70.8	81.5	83.1	
Main occupation (%)						
Housewife	86.2	88.3	75.0	75.9	81.4	
Farming	3.5	7.2	20.8	9.3	10.2	
Livestock	-	1.3	-	-	0.3	
Fisherman	-	-	-	1.8	0.5	
Other	10.3	3.2	4.2	13.0	7.6	
Education level (%)						
Illiterate	13.8	16.3	25.0	14.8	17.5	
Primary	65.5	49.7	37.5	50.0	50.7	
Secondary	17.2	24.8	33.3	31.5	26.7	
High school	-	7.8	4.2	3.7	3.9	
University	3.5	1.4	-	-	1.2	
Dialects (%)						
None (Spanish)	13.8	14.4	83.3	88.9	50.1	
Mayan	86.2	83.7	4.2	9.3	45.8	
Others	-	1.9	12.5	1.8	4.1	
Age of respondent (years)	54.3 ± 2.8^{a}	44.2 ± 1.2^{b}	46.0 ± 3.0^{ab}	48.0 ± 2.0^{ab}	46.3 ± 0.9	0.01
Family size (number of people)	4.0 ± 0.3	4.6 ± 0.1	4.1 ± 0.4	4.3 ± 0.3	4.5 ± 0.1	0.34
Farms' characteristics						
Farm size (ha)	0.10 ± 0.2	0.10 ± 0.1	0.30 ± 0.3	0.60 ± 0.2	0.20 ± 0.1	0.11
Livestock species						
Local chicken	25.8 ± 4.0	25.5 ± 1.7	27.4 ± 4.4	18.9 ± 2.9	24.4 ± 1.3	0.12
Turkey	6.7 ± 1.6	5.4 ± 0.7	6.9 ± 1.8	5.0 ± 1.1	5.6 ± 0.53	0.70
Duck	3.3 ± 1.2	1.7 ± 0.5	0.2 ± 1.4	3.1 ± 0.9	2.0 ± 0.4	0.16
Cattle	1.4 ± 1.1^{ab}	0.1 ± 0.5^{b}	3.9 ± 1.3^{a}	2.1 ± 0.8^{ab}	1.0 ± 0.4	0.01
Sheep	0.1 ± 1.1^{b}	1.2 ± 0.5^{b}	5.5 ± 1.3^{a}	0.5 ± 0.8^{b}	1.3 ± 0.4	0.01
Pig	0.3 ± 0.5^{b}	0.9 ± 0.2^{ab}	2.3 ± 0.6^{a}	0.4 ± 0.4^{b}	1.0 ± 0.2	0.04
Reasons for raising LC						
Consumption	82.8	87.6	87.5	68.5	83.1	
Cash income	13.8	12.4	12.5	20.4	14.2	
Ornament	3.4	-	-	11.1	2.7	

Means followed by different letters (a, b superscripts) in the same row are statistically different ($P < 0.05$); - not observed; ± standard error of means (SEM); Sig. Significance; % = percentage; ha = hectares; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Flock Structure and Productive Performance

In this study, flock size was 24.4 ± 1.3 birds per household (Table 1). In the CPY ecoregion a greater number ($P < 0.01$) of hens was found than in the other ecoregions. Flock structure was dominated by hens (8.7 ± 0.6), followed by pullets (4.8 ± 0.4), cockerels (4.8 ± 0.4), chicks (3.8 ± 0.4), and cocks (2.3 ± 0.2), with a sex ratio of four hens per cock (Table 2).

The number of eggs/hen/year was 45.8 ± 1.6 and egg weight was 54.9 ± 5.0 g (data not shown in tables); these eggs were produced in 2.9 ± 0.1 clutches of 15.3 ± 0.4 eggs each. Eighty six percent (13.2 ± 0.2 eggs) of the produced eggs were incubated with a hatchability of 75.0% (9.9 ± 0.2 chicks); however, only 84.8% (8.4 ± 0.2 chicks) of the hatched chicks were weaned, and these birds reached sexual maturity at around six months of age (Table 2).

Table 1.2. Local chicken flock structure and productive performance

Variables	Ecoregions WNY (n = 29)	CPY (n = 153)	LHSY (n = 24)	WSGM (n = 54)	Overall mean	Sig. (*P*-value)
Flock structure						
Cocks (> 21 weeks age)	2.5 ± 0.5	2.2 ± 0.2	1.5 ± 0.5	2.7 ± 0.3	2.3 ± 0.2	0.29
Hens(> 21 weeks age)	9.2 ± 1.8[b]	10.2 ± 0.8[a]	6.0 ± 2.0[b]	5.2 ± 1.3[b]	8.7 ± 0.6	0.01
Pullets (4 to 21 weeks age)	4.8 ± 1.3	4.8 ± 0.6	7.8 ± 1.4	3.6 ± 0.9	4.8 ± 0.4	0.27
Cockerels (4 to 21 weeks age)	5.4 ± 1.3	4.5 ± 0.6	7.1 ± 1.4	4.1 ± 0.9	4.8 ± 0.4	0.10
Chicks (0 to 4 weeks age)	3.9 ± 1.3	3.8 ± 0.6	5.0 ± 1.4	3.3 ± 1.0	3.8 ± 0.4	0.79
Flock sex ratio (female:male)	3:1	5:1	4:1	2:1	4:1	
Performance of chickens						
Egg/hen/year	47.8 ± 4.9	45.5 ± 2.1	47.3 ± 5.4	45.1 ± 3.6	45.8 ± 1.6	0.96
Egg/hen/clutch	16.7 ± 1.3	15.2 ± 0.6	15.2 ± 1.4	15.2 ± 1.0	15.3 ± 0.4	0.75
Clutches/hen/year	2.9 ± 0.2	2.9 ± 0.1	2.9 ± 0.2	3.2 ± 0.2	2.9 ± 0.1	0.39
Eggs incubated (%)	74.9	83.6	99.3	92.1	86.0	
Chicks hatched (%)	72.8	76.4	74.2	73.6	75.0	
Chicks weaned/hen/clutch (%)	86.8	86.6	83.0	81.6	84.8	
Age at sexual maturity (months)						
Hens	6.2 ± 0.4	6.3 ± 0.2	6.5 ± 0.4	5.7 ± 0.4	6.2 ± 0.1	0.25
Cocks	5.7 ± 0.4	6.0 ± 0.3	6.2 ± 0.4	6.1 ± 0.3	6.0 ± 0.1	0.84

Means followed by different letters (a, b superscripts) in the same row are statistically different ($P < 0.05$); ± standard error of means (SEM); Sig. Significance; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Source of the Birds and Housing Conditions

The main source of breeders was via purchasing (hens = 55.7% and cocks = 58.6%) and gifting or inheriting (43.0 and 35.0% for hens and cocks, respectively). Only a minor proportion of the birds (1.3% hens and 1.1% cocks) were obtained through government support programs with improved genotypes. Most of the farmers raised the birds under confined and semi-confined systems (80.1%). Chicken coops were predominantly built with wire mesh (59.6%) as walls, galvanized steel sheets (57.2%) as roofs, and a dirt floor (72.9%). Farmers offered feed directly on the dirt floor (36.6%) and water in recycled containers (59.5%); in the same context, hens laid eggs on the dirt floor and in cardboard boxes (50.2 and 31.9%, respectively; Table 3).

Table 1.3. Origin and housing conditions of local chickens

Variables	Ecoregions				Overall mean (%)
	WNY (n = 29)	CPY (n = 153)	LHSY (n = 24)	WSGM (n = 54)	
Origin of the first hen					
Purchased	51.7	58.2	50.0	63.0	55.7
Gift/heritage	48.3	36.6	50.0	37.0	43.0
Government support	-	5.2	-	-	1.3
Origin of the first cock					
Purchased	55.2	56.2	58.3	64.8	58.6
Gift/heritage	41.4	36.0	29.2	33.3	35.0
Government support	-	4.5	-	-	1.1
Hatched	3.4	3.3	12.5	1.9	5.3
Production systems					
Free range	3.5	9.1	37.5	29.6	19.9
Semi-confined	37.9	27.5	12.5	31.5	27.4
Confined	58.6	63.4	50.0	38.9	52.7
Material of the chicken coop					
Walls					
Wire mesh	82.1	70.5	26.7	59.0	59.6
Wood	7.2	20.9	73.4	20.5	30.5
Recycled material	10.7	8.6	-	20.5	9.9
Roof					
Tarred-cardboard sheet	32.1	35.3	6.7	5.1	19.8
Galvanized steel sheet	53.6	51.1	60.0	64.1	57.2
Recycled material	10.7	10.1	33.3	25.6	19.9
No roof	3.6	3.5	-	5.2	3.1
Floor					
Dirt floor	60.7	80.6	73.3	76.9	72.9
Concrete	17.9	19.4	26.7	7.7	17.9
Sand	21.4	-	-	15.4	9.2
Feeders					
Plastic/metal	27.6	33.4	12.5	35.2	27.2
Recycled containers	51.7	41.8	12.5	38.9	36.2
Dirt floor	20.7	24.8	75.0	25.9	36.6
Drinkers					
Plastic/metal	24.1	32.0	25.0	44.4	31.4
Recycled material	72.4	57.5	58.3	50.0	59.5
Stone	3.5	10.5	16.7	5.6	9.1
Nest					
Cardboard box	10.4	22.2	37.5	57.4	31.9
Recycled containers	24.2	17.7	-	1.9	10.9
Stone caves	10.4	17.6	-	-	7.0
Dirt floor	55.0	42.5	62.5	40.7	50.2

- not observed; % = percentage; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Management and Feeding

Mothers (76.3%) and fathers (14.4%) are the family members who take care of the birds; they feed them two to three times a day (35.6 and 58.3%, respectively). The chickens (> 4 weeks of age) are fed with corn (whole, broken or dough; 50.6%) and chicks (0 to 4 weeks of age) receive commercial feed (71.6%) and corn or dough (10.9%). Only scavenging chickens are supplemented with corn (whole, dough or tortilla) and wheat bran (70.2%), in order to improve production (meat and eggs; 38.9%), growth (36.7%), and health (24.4%). Additionally, 72.9% of farmers provide drinking water to their chickens, and the rest well-water (Table 4).

Table 1.4. Management and feeding of local chickens

Variables	Ecoregions				Overall mean (%)
	WNY (n = 29)	CPY (n = 153)	LHSY (n = 24)	WSGM (n = 54)	
Family member					
Mother	79.3	83.0	70.8	72.2	76.3
Father	13.8	6.5	20.8	16.7	14.4
Children	3.5	9.2	8.4	11.1	8.1
Grandparents	3.4	1.3	-	-	1.2
Feeding schedule for flock					
At dawn	6.9	4.3	10.4	2.8	6.1
At dawn/sunset	31.0	38.9	35.5	37.1	35.6
at dawn/noon/sunset	62.1	56.8	54.1	60.1	58.3
Feeding of the chickens (> 4 weeks age)					
Chickens scavenge free range	17.2	17.0	54.2	14.8	25.8
Waste (kitchen or market)	13.8	7.9	4.1	9.2	8.7
Corn (whole, broken or dough)	55.1	57.5	41.7	48.2	50.6
Commercial feed	3.6	7.7	-	27.8	9.8
Mixture of corn dough and wheat bran	10.3	9.9	-	-	5.1
Feeding of the chicks (0 to 4 weeks age)					
Chicks scavenge free range	3.5	5.9	-	5.6	3.7
Waste (kitchen or market)	3.4	2.6	4.2	5.5	3.9
Corn (whole, broken or dough)	17.3	15.0	-	11.2	10.9
Commercial feed	72.4	68.6	75.0	70.4	71.6
Mixture of corn dough and wheat bran	3.4	4.6	4.2	1.8	3.5
Rice	-	3.3	16.6	5.5	6.4
Type of supplement for chickens scavenge					
Corn (whole, dough or tortilla)	45.5	11.1	68.4	37.0	40.5
Commercial feed	-	33.3	-	25.9	14.8
Mixture of corn dough and wheat bran	27.2	51.9	26.3	29.6	33.7
Rice	27.3	3.7	5.3	7.5	11.0
Complementary reason					
Increased production (meat or eggs)	41.2	41.7	20.0	52.5	38.9
Faster growth	35.3	39.0	65.0	27.5	24.4
Improve health	23.5	19.3	15.0	20.0	36.7
Type of water provided					
Well-water	27.6	12.4	33.3	35.2	27.1
Drinking water	72.4	87.6	66.7	64.8	72.9

- not observed; % = percentage; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Sanitary Management

Most LC farmers (75.1%) clean their chicken coops at least once a week. Likewise, the majority of farmers do not vaccinate (69.3%) but deworm (61.7%) their birds. Rain (43.7%) is the principal factor associated with the period of time with the highest incidence of diseases, which coincides with the rainy season from June to September (44.1%). Flu and diarrhea are the diseases most frequently observed (46.9%). These diseases are controlled with drugs (50.7%) and home remedies (33.0%). Chicks (0 to 4 weeks of age) are more susceptible (47.8%) than the rest of the flock. Less than half of the flock died (60.4%) due to health issues (Table 5).

Table 1.5. Sanitary management of local chickens

Variables	Ecoregions				Overall mean (%)
	WNY (n = 29)	CPY (n =153)	LHSY (n = 24)	WSGM (n = 54)	
Cleaning of chicken coops (times per week)					
Zero	6.9	13.2	50.0	29.6	24.9
One	58.6	56.9	25.0	13.0	38.4
Two	27.6	18.8	16.7	20.4	20.9
Three	6.9	9.0	4.2	13.0	8.3
Seven	-	2.1	4.1	24.0	7.5
Vaccination					
Yes	34.5	27.0	33.3	27.8	30.7
No	65.5	73.0	66.7	72.2	69.3
Internal and/or external parasite control					
Yes	57.9	52.9	74.0	62	61.7
No	42.1	47.1	26.0	38	38.3
Predisposing factors for diseases					
Birds within and among flocks	13.8	14.0	25.0	13.2	16.5
Rainy season	31.0	56.7	41.7	45.3	43.7
Unknown	55.2	29.3	33.3	41.5	39.8
Favourable season for diseases					
March to June	32.1	37.3	33.3	35.3	34.5
June to September	28.6	44.7	50.0	52.9	44.1
September to December	14.3	12.7	12.5	9.8	12.3
December to March	25.0	5.3	4.2	2.0	9.1
Observed diseases					
Flu and diarrea	25.0	65.9	87.5	93.3	46.9
Bird pox	75.0	34.1	12.5	6.7	32.1
Diseases control					
Home remedies	46.4	43.4	12.5	29.6	33.0
Drugs	39.3	40.8	70.8	51.9	50.7
Sacrifice	3.6	4.6	4.2	3.6	4.0
Consult veterinarian	3.6	4.0	8.3	1.9	4.4
Nothing	7.1	7.2	4.2	13.0	7.9
Birds susceptible					
Cocks/hens	10.7	12.5	33.3	21.6	19.5
Pullets/cockerels	21.4	16.5	-	13.7	12.9
Chicks	57.1	49.3	41.7	43.1	47.8
All	10.8	21.7	25.0	21.6	19.8
Severity of losses					
More than half of the flock dies	22.2	36.4	20.8	25.5	26.2
Less than half of the flock dies	74.1	49.0	50.0	68.6	60.4
The whole flock dies	3.7	14.6	29.2	5.9	13.4

- not observed; n = sample size; % = percentage; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Breeding Practices in Local Chickens

Only a small proportion of the farmers (16.5%) try to improve the productivity of their LC by breeding methods. These methods include selecting within the flock (83.9%) or acquiring improved breeds (16.1%). Body size is the main trait that is taken into account to acquire breeders (hens and cocks) outside the flock or select them from among the farmer's birds. More than half of farmers select the eggs before incubation (61.9%; data not shown in tables). This selection is based on size (49.2%) and freshness (46.6%). On the other hand, hen selection depends on mothering ability (81.7%). Brooding seasons are from December to March (33.6%) and from March to June (31.9%). Prevention of broodiness in hens (88.7%) is performed by methods such as a bath or isolation (Table 6).

Table 1.6. Breeding method and selection criteria of local chickens

Variables	Ecoregions WNY (n=29)	CPY (n=153)	LHSY (n=24)	WSGM (n=54)	Overall mean (%)
Breeding practice					
Yes	17.2	11.1	20.8	16.7	16.5
No	82.8	88.9	79.2	83.3	83.5
Breeding methods					
Acquiring improved breeds	13.8	13.1	20.8	16.7	16.1
Selecting local chickens	86.2	86.9	79.2	83.3	83.9
Selection criteria for acquiring					
Cock					
Plumage colour and comb type	50.0	30.0	-	-	20.0
Body size	50.0	55.0	80.0	100.0	71.2
Age	-	15.0	20.0	-	8.8
Hen					
Plumage colour and comb type	25.0	25.0	-	-	12.5
Body size	25.0	45.0	75.0	80.0	56.2
Number of eggs	-	10.0	25.0	10.0	11.3
Mothering ability	50.0	20.0	-	10.0	20.0
Selection criteria for breeders within flock					
Cock					
Plumage colour and comb type	57.1	32.6	26.1	13.2	32.2
Body size	32.1	56.3	65.2	77.4	57.7
Resistance to diseases	3.6	4.2	-	1.9	2.4
Meat yield	-	5.6	-	1.9	1.8
Paternal fertility	7.2	1.3	8.7	5.6	5.7
Hen					
Plumage colour and comb type	13.9	6.2	8.3	5.7	8.5
Body size	24.1	44.5	29.2	60.4	39.5
Resistance to diseases	-	2.1	4.1	3.7	2.5
Number of eggs	24.1	21.9	4.2	11.3	15.4
Mothering ability	37.9	25.3	54.2	18.9	34.1
Selection of egg for hatching					
Large size	40.9	64.4	44.4	47.2	49.2
Freshness	59.1	30.0	55.6	41.7	46.6
Most productive chickens	-	5.6	-	11.1	4.2
Selection of hen for hatching					
Body size	-	20.4	31.6	21.2	18.3
Mothering ability	100.0	79.6	68.4	78.8	81.7
Favorable season for incubation					
March to June	20.7	43.5	20.8	42.6	31.9
June to September	20.7	24.5	33.3	31.4	25.7
September to December	3.4	6.8	8.4	9.3	8.8
December to March	55.2	25.2	37.5	16.7	33.6
Prevent broody hens					
Yes	78.6	96.7	100.0	79.6	88.7
No	21.4	3.3	-	20.4	11.3

- not observed; % = percentage; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Marketing and Use of Local Chickens

Chicken meat (90.9%) and eggs (92.7%) were the main products consumed at home. Families consume LC meat 3.5 ± 2.9 times a month, and 17.0 ± 1.0 eggs a week (data not shown in tables). Bird's BW (69.2%) was the selection criterion for chicken meat consumption in the households. More than half of farmers (60.5%) sell their chickens. Live chicken (98.0%) is the most common way for selling, and the price is determined by BW (92.2%). The farmers sell 1.6 ± 0.2 birds per month, obtaining $8.99 ± 0.93 USD based on an exchange rate of $18.57 Mexican pesos per one USD (data not shown in tables). On the other hand, 50.9% of farmers do not sell the eggs they produce. Nevertheless, those farmers who do sell them market 7.6 ± 0.7 eggs per week and obtain $3.82 ± 0.33 USD (data not shown in tables). For the majority of the farmers (57.1%), the marketing of LC products (meat and eggs) represents their main source of income; these products are mainly sold directly to the consumer (94.6%) (Table 7).

Table 1.7. Consumption and marketing of local chickens

Variables	Ecoregions				Overall mean (%)
	WNY (n=29)	CPY (n=153)	LHSY (n=24)	WSGM (n=54)	
Consumption of local chicken meat					
Yes	100.0	99.4	95.8	68.5	90.9
No	-	0.6	4.2	31.5	9.1
Egg consumption					
Yes	100.0	97.4	95.8	77.8	92.7
No	-	2.6	4.2	22.2	7.3
Criteria for meat consumption					
Body weight	82.7	78.1	60.9	55.1	69.2
Age	13.8	17.2	21.7	30.6	20.8
Non-productive	3.5	4.7	17.4	14.3	10.0
Sale of local chickens					
Yes	58.6	60.8	70.8	51.9	60.5
No	41.4	39.2	29.2	48.1	39.5
Product presentation					
Whole carcass chicken	-	1.1	-	3.5	1.2
Live	100.0	98.9	100.0	93.1	98.0
Cooked	-	-	-	3.4	0.8
Price determination					
Plumage colour and comb type	5.9	12.6	5.9	6.9	7.8
Body weight	94.1	87.4	94.1	93.1	92.2
Sale of eggs					
Yes	48.3	51.0	58.3	38.9	49.1
No	51.7	49.0	41.7	61.1	50.9
Sales contribute to household income					
Yes	44.8	56.1	83.3	42.6	56.7
No	55.2	43.9	16.7	57.4	43.3
Livestock species as income source					
Local chicken	58.6	67.3	70.8	31.5	57.1
Turkey	10.3	18.3	-	11.1	9.9
Others	7.0	9.2	20.9	5.6	10.7
None	24.1	5.2	8.3	51.8	22.3
Market flow of local chickens					
Direct consumer	100.0	100.0	100.0	78.6	94.6
Merchant intermediary	-	-	-	21.4	5.4

- not observed; n = sample size; % = percentage; WNY = wetlands of northern Yucatan; CPY = central plain of Yucatan; LHSY = low hills of southern Yucatan; WSGM = wetlands of the southern gulf of Mexico.

Constraints on Backyard Chicken Production

Insufficient production (46.0%) and a lack of market venues (42.5%) were some of the obstacles for the marketing of LC products. Feed shortages (36.5%), diseases (21.9%), and predators (13.5%) were identified as the major challenges for LC production, a situation which is aggravated by the lack of technical assistance services (83.9%). Despite difficulties for raising LC, 88.9% of respondents would like to have more chickens in their backyard, in order to have a source of food and income (data not shown in tables).

1.5. DISCUSSION

In most developing countries, rural poultry production plays a significant role in improving the nutritional status, income, food security and livelihood of many smallholders (Abubakar et al., 2007). The results of this study showed that backyard poultry production was mainly done by housewives, most of whom have a formal education and speak a Mayan dialect. The average age of farmers was 46.3 ± 0.9 years and mean family size was 4.5 ± 0.1 people. Results of the present study show that housewife age and family size coincide with those reported by Flota-Bañuelos et al. (2016) who mentioned values of 45.7 ± 14.7 years and 4.2 ± 1.9 people. Likewise, family size and proportion of family members that have a formal education and speak the Mayan dialect, have similar values in data reported by INEGI (2010); 3.7 people, 90.9% and 78.0%, respectively. The fact that women are the family members in charge of backyard poultry production activities may be explained by the time they spend at home as housewives and because caring for the birds is light work. Farm size or total land owned per household found in this study was 0.2 ± 0.1 hectares. Local chickens, turkeys, and ducks were the most important livestock species on the farm. Provision for food and cash income were the main reasons for raising LC. The livestock species present in the backyards found in this study are in line with those reported by Candelaria-Martínez et al. (2016) who pointed out that chickens (70.7%) and turkeys (16.4%) were the main animal species in the backyards of Campeche State. These authors, as in the case of the present study, report that poultry provides a source of food and cash income for rural farmers. Similar results about the use of poultry were found by Okeno et al. (2012) and Alemayehu et al. (2015) in backyards of developing countries such as Kenya and Ethiopia, respectively. On the other hand, the farm size observed in the present study is greater than the values (0.08 to 0.10 hectares) reported by Flota-Bañuelos et al. (2016) and Gutiérrez-Triay et al. (2007).

The flock size found in this research was 24.4 ± 1.3 birds, and its structure was dominated by hens, followed by pullets, cockerels, chicks, and cocks. These results fall within the range reported in backyards in rural areas of Campeche by Candelaria-Martínez et al. (2016) and Flota-Bañuelos et al. (2016), who found 20.7 and 24.1 chickens per flock, respectively. In addition, Okeno et al. (2012) observed a flock size of 22.4 birds in backyards of Kenya, but flock structure was different to the findings of the present research. According to the farmers, the higher number of hens in the flock is due to their objective to increase both egg and chick production. The number of clutches (2.9 ± 0.1) found in this study was similar to the one found by Centeno-Bautista et al. (2007) who recorded 2.3 clutches per year. Eggs that are brooded have a hatchability of 75.0%; however, only 84.8% of the hatched chicks were weaned, and these birds reached sexual maturity at about six months of age. Hatchability percentage of eggs in this study was higher than the values (61.3%) mentioned by Juárez-Caratachea and Ortiz-Alvarado (2001) and Gutiérrez-Triay et al. (2007), whereas the age at sexual maturity of the chickens is similar to that found by Juárez-Caratachea and Ochoa (1995).

The source of breeders was via purchasing and gifting or inheriting, which agrees with earlier observations reported by Centeno-Bautista et al. (2007) who found that breeders and replacement animals are acquired by purchasing. Likewise, authors in other countries mentioned that farmers bought chickens to raise them, whereas some chickens were obtained as a gift or via hatched eggs using broody hens at home (Gondwe and Wollny, 2007; Halima et al., 2007). On the other hand, only a small proportion of improved birds was obtained by farmers through government support programs. Most of the farmers raised birds in confined and semi-confined systems and have chicken coops built predominantly with wire mesh as walls, galvanized steel sheets as roofs and a dirt floor. According to the farmers, LC are kept confined because of the financial support they received from the Mexican government for the construction of chicken coops (SAGARPA, 2016). Farmers offered feed directly on the dirt floor and water was provided in recycled containers, and hens laid eggs on the dirt floor and in cardboard boxes. These results partially coincide with those found by Camacho-Escobar et al. (2011) in Oaxaca, Mexico and in other developing countries (Abdelqader et al., 2007), where chicken coops were equipped with feeders and drinkers made with recycled kitchen containers and the hens lays their eggs on the dirt floor or in cardboard boxes; the use of locally available materials reduces input costs. Farmers that did not have chicken coops (15.4%) mentioned that a lack of money (67.5%) is the main constraint for their construction; therefore, they practice the free-range system.

Regarding the management and feeding of LC, the parents take care of the birds, they feed them two or three times a day. Similarly, Cuca-García et al. (2015) reported that LC are mainly cared for by housewives, children and senior citizens. Regarding feeding frequency, results of this study are in contrast with those reported by Camacho-Escobar et al. (2011), who found that the rural people of Oaxaca and Puebla, Mexico, fed their chicks from five to six times a day. In addition, Atehortua et al. (2015) observed in Colombia that a group of surveyed families fed their hens once a day, whereas others offered feed more frequently. Chickens (> 4 weeks of age) were fed with corn (whole, broken or dough), whereas chicks (0 to 4 weeks of age) received commercial feed and corn. Flock feeding practices agree with those found by Candelaria-Martínez et al. (2016), who mentioned that the main feedstuff for birds was corn (91.0%). Although the inclusion of local feedstuffs such as mucuna beans (*Mucuna pruriens* L.), chaya (*Cnidoscolus aconitifolius*) leaf meal, and tropical tree legume (*Leucaeca leucocephala*) for poultry feeding has been reported (Sarmiento-Franco et al., 2002; Trejo et al., 2004; Flores and Bautista, 2012), the use of alternative local feedstuffs in Campeche, Mexico is rare. This could be attributed to the fact that rural people are unaware of the nutritional value of these feed sources. Only scavenging chickens were supplemented with corn and wheat bran, in order to improve production, growth and health. Local chickens in a free-range system depend on field grains, insects, earthworms, green matter, crop residues, homestead pickings and kitchen waste for their feeding as reported by Bhuiyan et al. (2005). Other research findings (Addisu et al., 2013) indicate that in Ethiopia chickens are supplemented to increase growth, meat yield and egg production.

In the present study, a high proportion of farmers cleaned their chicken coops at least once a week and did not vaccinate but deworm their flocks. The cleaning frequency of the chicken coops was similar to that reported by Addisu et al. (2013). In addition, the lack of vaccination programs found in this study coincides with the reports of Centeno-Bautista et al. (2007) in other regions of Mexico. On the other hand, farmers considered rain as the main factor associated with the period of time with the highest incidence of diseases, which coincides with the rainy season from June to September. The most common illnesses observed are the flu and diarrheal diseases, which are controlled with drugs and home remedies. Chicks are more susceptible than the rest of the flock; additionally, less than half of the flock dies due to health issues. The season with the highest incidence of diseases is similar to that reported by Yemane et al. (2013) in Ethiopia. These authors found that the severity of the diseases was higher during the rainy season (75.4%) than in the dry season (24.6%). They also found that disease treatment is based on home remedies involving the use of, among other substances, Tabaco leaves, lemon juice and cooking oil, which is similar to the findings in the present study. In addition, chicken diseases found in this research coincide with those reported by Centeno-Bautista et al. (2007) and Candelaria-Martínez et al. (2016) in the central-south region of Mexico.

Only a small proportion of farmers attempt to improve LC productivity; these farmers try to improve their flock productivity by either selecting LC or acquiring improved breeds. Body size is the main trait that is taken into account to acquire breeders outside the flock or select them within farmers' birds. This result is in line with that reported by Addisu et al. (2013), who found that some farmers implement breeding practices. Selection criteria identified in this study are similar to those found in other backyard poultry production systems (egg production, BW and feather color) in other developing countries (Zewdu et al., 2013). Likewise, more than half of the producers select the eggs before incubation, based on size and freshness; hen selection depends on mothering ability. Selection practices prior to incubation mentioned by farmers are similar to those reported in another study on LC (Addisu et al., 2013), where egg selection is based on size and whether they come from improved birds. Findings of the present study suggest that farmers improve the flock´s productivity using their experience. They select eggs and broody hens with the best production features because these traits will determine the production potential of the new flock. In addition, most farmers prefer mating among LC due to their advantage of being well adapted to local environmental conditions compared to improved genotypes.

Chicken meat and eggs are a source of food for farmers and their families. Bird's BW was the selection criterion for chicken meat consumption in the households. Candelaria-Martínez et al. (2016) reported that 86.0% of backyard livestock production is used for family consumption. In addition, Atehortua et al. (2015) mentioned that more than 60.0% of families slaughter birds for household consumption, and the criteria used to consume the birds were BW and low hen productivity. On the other hand, farmers who do not sell eggs practice incubation in order to obtain more birds. Nevertheless, some farmers sell 1.6 ± 0.2 birds per month and 7.6 ± 0.7 eggs per week to get cash. These results agree with those reported by Moreki (2010) in Africa, who found that chickens and eggs are rarely sold, but that the latter are used for hatching. This result is not in line with findings reported by Addisu et al. (2013) who mentioned that most farmers sell their chicken products to small retailers at low prices. Moreover, Hamilton-West et al. (2012) observed that the income generated by backyard poultry can be considered low, because most of the farmers wait for an opportunity to sell their products to neighbors or tourists who pass by the farm and few of them try to sell their products at local markets.

Finally, insufficient production and a lack of market venues were some of the obstacles for marketing of LC products, whereas feed shortages, diseases, and predators were the main challenges for LC production, which is aggravated by the lack of technical assistance services. However, despite difficulties for raising LC, 88.9% of respondents would like to have more chickens in their backyard, in order to have a source of food and generate household income. Centeno-Bautista et al. (2007) found that the main limitations on chicken production in the rural communities of Puebla, Mexico are predators, diseases, and a lack of technical assistance; these results agree with this investigation. Similarly, Addisu et al. (2013) reported that diseases (60.13%), feed shortages (20.59%), and predators or theft (19.28%) were the main constraints on backyard chicken production in North Wollo, Ethiopia. The lack of technical assistance observed in this research is consistent with findings in other developing countries; for example, Okeno et al. (2012) reported that in Kenya only a few farmers had extension services from government officers, but they were not frequently available and did not offer extension services targeting indigenous chicken production. Thus, results of this study suggest that extension services are necessary to improve the management, housing conditions, feeding, breeding, and health of LC. It thus appears that increased and better LC production may contribute to food security and poverty reduction of rural people in Campeche State, Mexico.

In conclusion, LC play a significant role in the household livelihood security of the rural people of Campeche State, Mexico because chickens are a source of animal protein and cash income. In addition, LC have the advantage of being well adapted to local environmental conditions, which make them an important genetic resource that can be more efficiently used. Factors such as inadequate nutrition, diseases, predators and a lack of technical assistance services were the major challenges for LC production. Additionally, the characterizing the backyard poultry production system is a necessary step in the development of a program for the utilization of local poultry genetic resources under the natural environmental conditions of Campeche State, Mexico, because it helps to identify objectives and selection criteria, and establish the scope of the program.

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CHAPTER II. COMPARISON OF FOUR NONLINEAR GROWTH MODELS IN LOCAL CHICKENS OF MEXICO

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2.1. ABSTRACT

Animal growth is a complex and dynamic process that involves physiological and morphological changes from hatching to maturity. It is defined as the increase in body size per time unit. Mathematical functions, called growth models, have been used to explain the growth patterns. The aim of this study was to compare the Gompertz-Laird, Logistic, Richards and Von Bertalanffy growth models for determining the best one that fits the data of the Mexican local chickens (**MXLC**). Three hundred forty-seven MXLC were individually weighed from hatching until 177 d of age. Birds were fed a starter diet (0-18 d of age; 19% CP and 3,000 kcal of ME/kg) and grower diet (19-177 d of age; 18% CP and 2,800 kcal of ME/kg). Data were analyzed using PROC NLIN for the non-linear growth curve fitting. The determination coefficient (**R^2**), Akaike' (**AIC**) and Bayesian information criteria (**BIC**) were used to compare the goodness of fit for models. The Von Bertalanffy (R^2: 0.9382; 0.9415; AIC: 2,224.1; 2,424.8; BIC: 2,233.5; 2,434.3, for females and males, respectively) was the best models explaining the growth of birds. On the other hand, both the Gompertz-Laird and Logistic models overestimated the initial BW and underestimated the final BW of MXLC. Females reached age of maximum growth faster than males. The asymptotic weight was higher in males (3,011.3 g) than in females (2,011.6 g). Body weight at inflection point was 892.2 g at 64.3 d of age for males and 596.0 g at 54.4 d for females. In conclusion, the best fit of the data was obtained with the Von Bertalanffy growth model; the information is intended to serve as the basis for utilizing local poultry genetic resources.

Keywords: growth curves, growth parameters, non-linear models, local chickens, Mexico

2.2. INTRODUCTION

The production of Mexican local chickens (**MXLC**) in rural communities of Mexico provide household livelihood security, animal protein and economic income to families. However, the productive performance of MXLC is low compared to commercial breeds (Segura-Correa et al., 2004; Okeno et al., 2012). Body weight of local chickens (**LC**) is an important trait for farmers. This characteristic is heritable so that it could be improved by means of breeding programs (Osei-Amponsah et al., 2013). Animal growth is a complex physiological and morphological process from hatching to maturity. It is defined as the increase in BW and organs size per unit of time or age increasing (Yang et al. 2006; Kaplan and Gürcan, 2018). Animal growth has been summarized using mathematical equations or growth curves that result in mathematical parameters that are biologically interpretable (Tzeng and Becker, 1981; Aggrey, 2002; Yang, 2006). Additionally, growth mathematical functions can be used for predict daily energy, protein, and mineral dietary requirements, suitable slaughter age, and age of sexual maturity (Darmani-Kuhi et al., 2010; Kebreab et al., 2011; Nahashon et al., 2010; Kaplan and Gürcan, 2018). In developing countries, some researchers have studied the growth of LC using Gompertz, Logistic, Richards (Norris et al., 2007; Olawoyin et al., 2007; Magothe et al., 2010; Rizzi et al., 2013 and Osei-Amponsah et al., 2014) and Von Bertalanffy models (Yang et al., 2006; Ngeno et al., 2010; Zhao et al., 2015). These non-linear models describe growth of LC but each one has different characteristics and limitations (Norris et al., 2007). For this reason, it is very important to choose the model that best describe the growth pattern. In Mexico, no research has been carried out to describe the growth pattern of LC, a lot less, have been developed programs aimed at improving local poultry genetic resources. Therefore, the aim of this study was to compare the Gompertz-Laird, Logistic, Richards and Von Bertalanffy growth models to identify the best one describing the growth pattern of MXLC.

2.3. MATERIALS AND METHODS

Study Sites

This study was conducted at the experimental chicken house at Colegio de Postgraduados, Campus Campeche, Mexico. The environmental temperature ranges from 18.0 to 30.0°C, rains are abundant during the summer (June to September), and the total annual precipitation of 1,600 mm (INEGI, 2014). The period of study went from December 2016 to September 2017.

Chickens and Environmental Conditions

A total of 24 cocks and 76 hens were randomly collected from the backyards of rural communities of Campeche State. Chickens were pedigree-mated by artificial insemination (sex ration, 1 cock: 3 hens) to hatch 347 chicks. Chicks were given *ad libitum* access to feed and water. The feeding program was divided in two phases: a starter diet (from hatch until 18 d of age) containing 19.0% crude protein and 3,000 kcal ME/kg and a grower diet (19 to 177 d of age) containing 18.0% crude protein and 2,800 kcal ME/kg (Table 1). All birds were weighed every third day until 57 d of age; subsequently, they were weighed every 14 d until 177 d of age. All procedures were performed according to the guide for care and use of experimental animal approved by the General Academic Council of Colegio de Postgraduados.

Table 2.1. Composition of experimental diets of Mexican local chickens

Ingredient (%)	Starter	Grower
Corn	64.20	61.92
Soybean meal	30.78	28.95
Soybean oil	0.87	-
Calcium carbonate	1.40	1.40
Orthophosphate	1.47	1.49
Lysine	-	0.05
Methionine	0.09	0.10
Threonine	0.09	0.12
Choline	0.21	0.21
Vitamin-mineral premix[1]	0.60	0.60
Salt	0.30	0.30
Sand[2]	-	4.85
Calculate level (%)		
Metabolizable energy, kcal/kg of diet	3,000	2,800
Crude protein	19.00	18.00
Calcium	0.85	0.85
Available P	0.40	0.40
Methionine	0.41	0.41
Methionine + cystine	0.75	0.73
Lysine	1.02	1.00
Sodium	0.17	0.16

[1]Provided per kilogram of diet: retinyl acetate, 9,000 IU; cholecalciferol, 2,500 IU; Dl-α-tocopheryl acetate, 20 IU; menadione sodium bisulfite complex, 3.0 mg; riboflavin, 8.0 mg; cobalamin, 0.015 mg; pantothenic acid, 10 mg; niacin, 40 mg; folic acid, 0.5 mg; choline, 300 mg; biotin, 0.055 mg, thiamine, 2.0 mg; iron, 65.0 mg; zinc, megnesioum,100; manganese, 100 mg; copper, 9.0 mg; selenium, 0.3 mg; iodo, 0.9 mg. [2]Sand was used as an inert filler in diet.

Growth Models

Four growth models (Von Bertalanffy, Richards, Gompertz-Laird and Logistic) were chosen to describe the growth pattern of MXLC.

Von Bertalanffy Model

Von Bertalanffy model has been used to describe the growth of indigenous chicken (Yang et al., 2006; Ngeno et al., 2010; Adenaike et al., 2017) using the equation:

$$W_t = W_A * \left(1 - B * \exp^{(-K*t)}\right)^3$$

Where W_t is the BW of chicken at time t, W_A is the asymptotic weight or mature weight, K is the maximum relative growth (per day), and B is the integration constant. Age of maximum growth (ti) and BW at age of inflection point (W_I) were estimated as follows: $ti = \ln(3b)/k$ and $W_I = A*8/27$ (Goshu and Koya, 2013).

Richards Model

The following equation describes the Richards growth model:

$$W_t = W_A\left[1-(1-m)\exp\left[-K(t-ti)/m^{m/(1-m)}\right]\right]^{1/(1-m)}$$

Where W_t is the BW of chicken at time t, W_A is the asymptotic weight or mature weight, K is the maximum relative growth (per day), ti is the age at maximum rate of growth (days), and m is a shape parameter, with the property that $m^{1/(1-m)}$ is relative weight at ti (Richards, 1959; Aggrey, 2002).

Gompertz-Laird Model

The following equation describes the Gompertz-Laird growth curve:

$$W_t = W_0 \exp\left[\left(L / K\right)\left(1 - \exp - Kt\right)\right]$$

Where W_t is the BW of chicken at time t, W_0 is the initial (hatch) BW, L is the instantaneous growth rate (per day), K is the rate of exponential decay of the initial specific growth rate.

Age of inflection point (ti) and asymptotic weight (W_A) were estimated as follows: $ti = \left(1/K\right)\log\left(L/k\right)$ and $W_A = W_0 \exp\left(L/K\right)$ (Laird et al., 1965; Aggrey, 2002).

Logistic Model

To estimate the expected BW at specific age, the following equation describes the logistic growth model:

$$W_t = W_A / \left[1 + \exp - K\left(t - ti\right)\right]$$

Where W_t is the BW of chicken at time t, W_A is the asymptotic weight or mature weight, K is the exponential growth rate, and ti is the age at the inflection point (Robertson, 1923; Aggrey, 2002).

Statistical Analysis

The models were fitted to the data using the PROC NLIN of SAS Institute Inc. (version 9.3, 2011). The Marquardt iterative procedure was used to find the values of the model parameters that minimizes the sums of the squared deviations between observed and fitted values.

Goodness-of-fit Criteria

Three criteria were used to compare the goodness-of-fit of the models: 1) Coefficient determination: $R^2 = 1 - \left(SSE / SST\right)$, 2) Akaike' information criterion: $AIC = n * \ln\left(SSE / n\right) + 2k$, and 3) Bayesian information criterion: $BIC = n * \ln(SSE/n) + k * \ln(n)$; where SSE is the sum of squares of errors, SST is the total sum of squares, n is the number of observations, k is the number of parameters, and $\ln$ is the natural logarithm. The preferred model is the one with the minimum AIC and BIC values (Narinc et al., 2013), and for the case of the coefficient determination the values must be similar or close to 1.

2.4. RESULTS

Overall means and standard deviations of BW of MXLC are presented in Table 2. For Gompertz-Laird model, the average predicted hatching weight was higher than the observed weight for females and males (51.1 *vs* 36.5 g and 53.5 *vs* 37.2 g, respectively). The initial growth rate of females (0.0751) was lower than males (0.0765). On the other hand, pullets had a faster rate of decay or maturation rate for BW than cockerels (Table 3).

Table 2.2. Body weight at different ages of the Mexican local chickens

Age (d)	Body weight (g)	
	Male (n = 177)	Female (n = 170)
0	37.2 ± 4.7	36.5 ± 5.2
3	51.9 ± 8.3	49.9 ± 7.7
6	63.3 ± 9.6	60.5 ± 9.5
9	81.2 ± 14.9	76.1 ± 13.4
12	101.9 ± 17.6	95.5 ± 16.1
15	130.9 ± 24.2	121.4 ± 21.5
18	163.0 ± 30.3	150.8 ± 25.8
21	196.7 ± 38.8	181.6 ± 33.2
24	228.0 ± 43.3	207.7 ± 35.0
27	259.7 ± 49.5	232.9 ± 40.5
30	303.1 ± 59.2	270.1 ± 46.5
33	342.9 ± 68.2	304.0 ± 51.3
36	390.0 ± 78.4	348.9 ± 59.7
39	433.3 ± 86.7	382.4 ± 68.3
42	487.8 ± 94.1	428.1 ± 75.5
45	543.9 ± 108.7	468.8 ± 84.2
48	582.8 ± 116.0	500.5 ± 87.8
51	645.6 ± 126.6	549.9 ± 95.3
54	697.3 ± 133.1	594.3 ± 103.3
57	768.5 ± 148.6	644.5 ± 113.1
72	1,051.4 ± 203.8	850.1 ± 151.4
87	1,292.9 ± 241.8	1,023.2 ± 174.0
102	1,542.8 ± 268.6	1,191.3 ± 209.3
117	1,787.7 ± 323.1	1,323.4 ± 209.6
132	1,992.4 ± 342.2	1,445.0 ± 244.1
147	2,141.9 ± 364.5	1,524.9 ± 257.8
162	2,268.3 ± 377.3	1,641.5 ± 298.1
177	2,409.2 ± 410.7	1,749.3 ± 306.6

± standard error of means (SEM)

The relative growth predicted by the Richards and Von Bertalanffy models, and the exponential growth rate predicted by the Logistic model, was higher in females than in males (Table 3). Hens reached age of maximum growth faster than cocks for all the models. The difference between sexes was 9.0, 8.5, 11.9, and 9.9 d for Gompertz-Laird, Logistic, Richards, and Von Bertalanffy models, respectively (Table 3).

The lowest predicted asymptotic weight in hens and cocks (1,552.3 and 2,356.9 g, respectively) was obtained using the Logistic model. Whereas the highest asymptotic weight was estimated with Richards model for hens (2,012.8 g), and Von Bertalanffy model for cocks (3,011.3 g) (Table 3).

Table 2.3. Parameters predicted of the growth models for Mexican local chickens

Model	Male (n = 177)	Female (n = 170)
Gompertz		
Hatching weight (W_0)	53.5	51.1
Asymptotic weight (W_A)	2,683.1	1,839.1
Initial growth rate (L)	0.0765	0.0751
Rate of decay (K)	0.0195	0.0210
Age of maximum growth (t)	69.8	60.8
Logistic		
Asymptotic weight (W_A)	2,356.9	1,652.3
Exponential growth rate (K)	0.0367	0.0380
Age of inflection point (ti)	80.9	72.4
Richards		
Asymptotic weight (W_A)	2,875.1	2,012.8
Maximum relative growth (K)	0.0065	0.0068
Age of maximum growth (ti)	66.3	54.4
Shape parameter (*m*)	0.7752	0.6651
Von Bertalanffy		
Asymptotic weight (W_A)	3,011.3	2,011.6
Maximum relative growth (K)	0.0137	0.0152
Age of maximum growth (ti)	64.3	54.4
Body weight of inflection point (W_I)	892.2	596.0
Integration constant (B)	0.8040	0.7628

Based on the three goodness-of-fit criteria (R^2; AIC and BIC), the Von Bertalanffy model produced the best fitting of the data (Table 4) for female and males (Figures 1 and 2, respectively).

Table 2.4. Goodness-of-fit criteria for the studied growth models

Sex	Model	R^2	AIC	BIC
Male	Gompertz	0.9412	2,425.5	2,435.0
	Logistic	0.9360	2,440.9	2,450.4
	Richards	0.9415	2,426.5	2,439.2
	Von Bertalanffy	0.9415	2,424.8	2,434.3
Female	Gompertz	0.9374	2,226.2	2,235.6
	Logistic	0.9305	2,243.9	2,253.3
	Richards	0.9382	2,226.1	2,238.6
	Von Bertalanffy	0.9382	2,224.1	2,233.5

R^2 = coefficient determination; AIC = Akaike' information criterion; BIC = Bayesian information criterion.

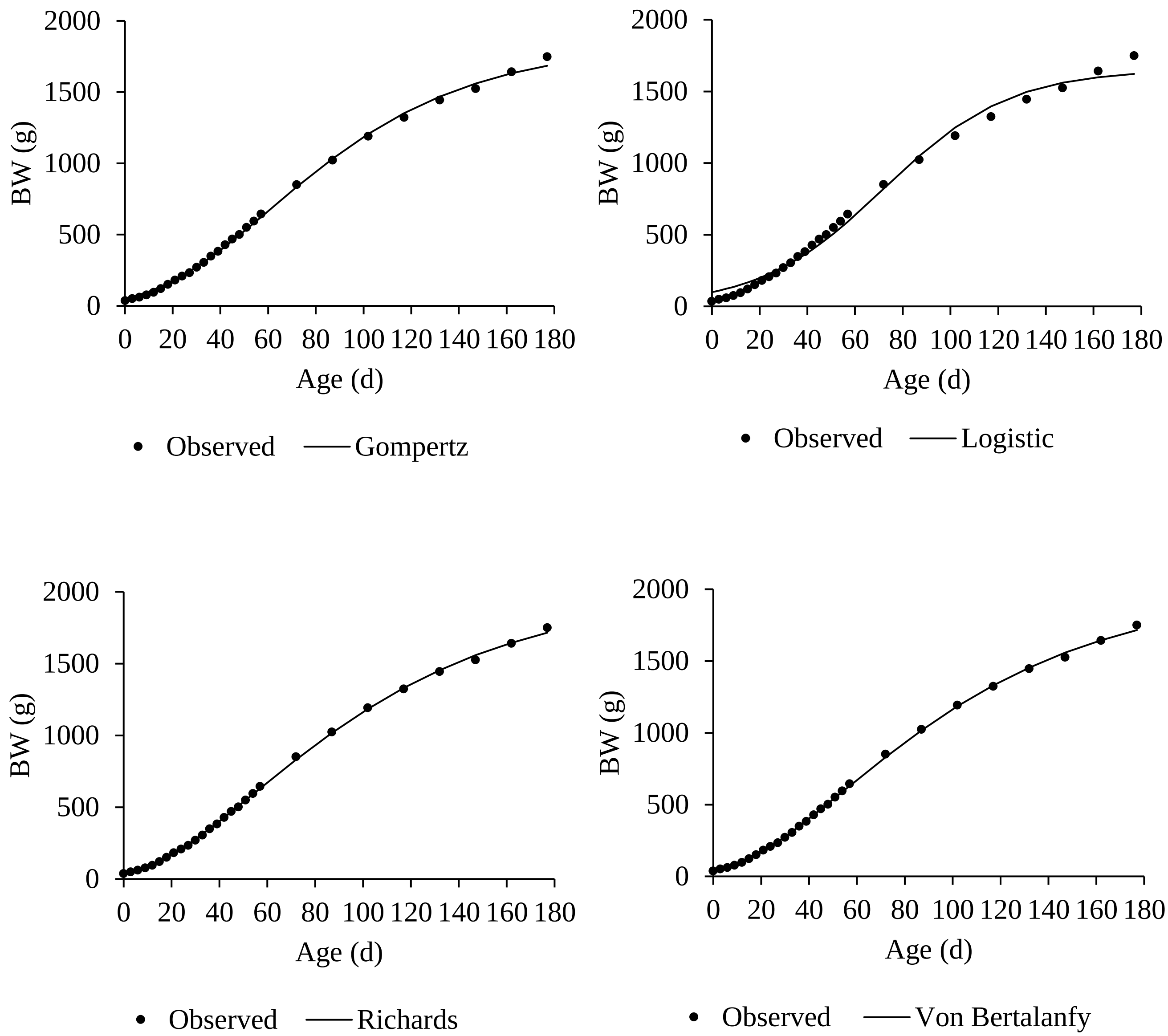

Figure 2.1. Growth curve for females predicted by four growth models in comparison to the observed data.

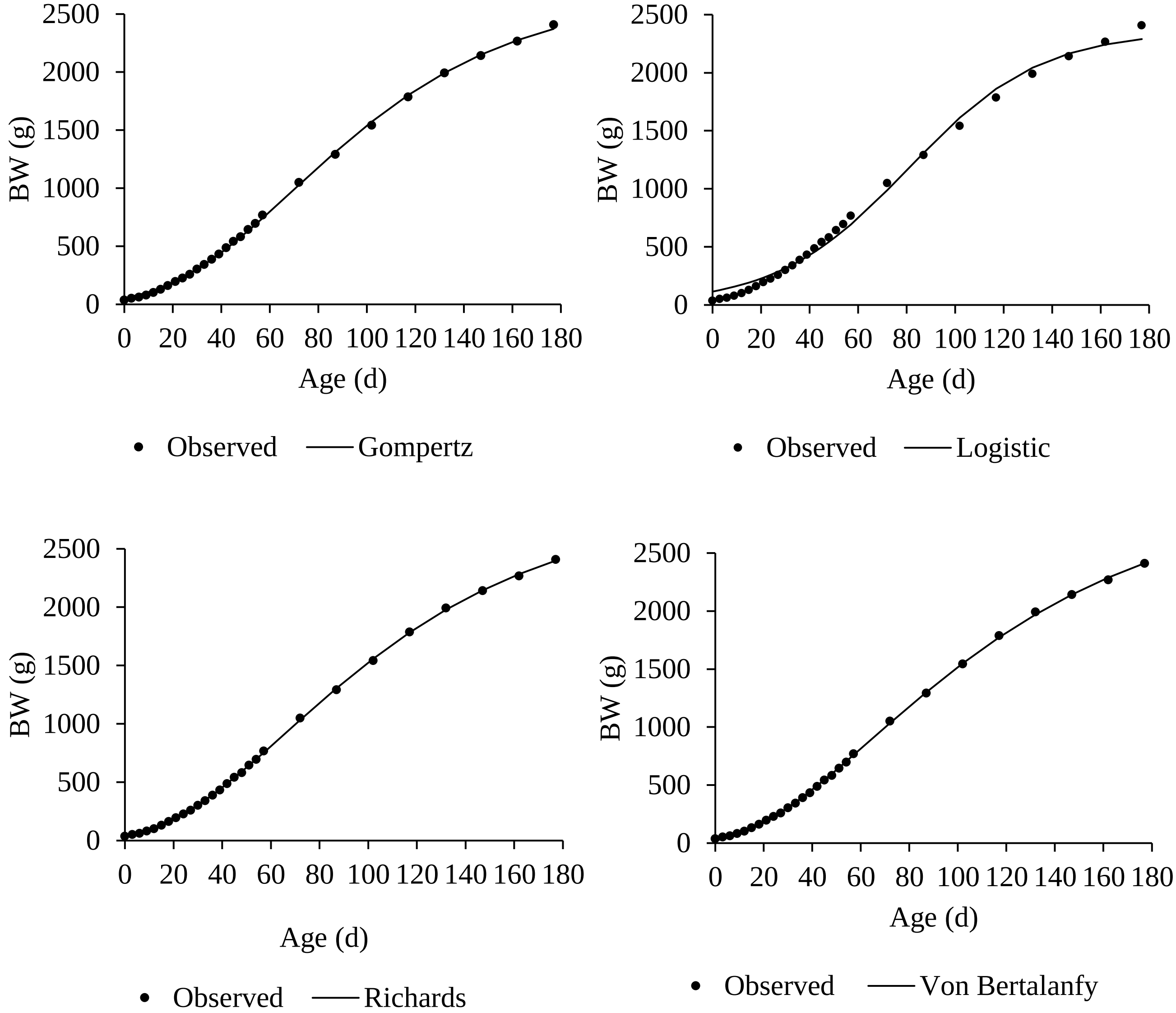

Figure 2.2. Growth curve for males predicted by four growth models in comparison to the observed data.

2.5. DISCUSSION

Growth parameters provided information about age and weight of maximum growth, growth rate and asymptotic weight in animals. Hatching weight predicted by Gompertz-Laird model for females and males (51.1 and 53.5 g, respectively) was 3.6 and 8.9 g higher than those reported by Aggrey (2002) for unselected random mating Athens-Canadian chickens population (47.7 g for females and 44.6 g for males). The Gompertz growth function usually overestimates hatching weight, to improve fitting of the data to model, Barbato (1991) suggested that hatching weight should be measured and not used as estimated parameter of the model. The results agree with those reported by Magothe et al. (2010) in Kenya, who observed that Gompertz model overestimated the initial weight in indigenous chicken.

The initial growth rate was lower in females than in males. Mignon-Grasteau (1999) found a similar pattern, females had a slow initial growth rate (0.0979), however, the growth values obtained by this author for unselected chickens were best than those reported in the present study. In contrast, the initial growth rate obtained by Magothe et al. (2010) for indigenous chicken (0.0599) was lower than the average obtained for both sexes of MXLC (0.0758). Results of the present study show that maturation rate was not in line with findings reported by Aggrey (2002) who mentioned that maturation rate of 0.0216 for females and 0.0224 for males, in an unselected chicken population. Similarly, in Nigeria Adenaike et al. (2017) reported a maturation rate of 0.1712 and 0.1685 in naked neck and normal feathered chickens, respectively. Besides, they mentioned that a low value of maturation rate indicate delayed maturity and high value indicate accelerated maturity. On the other hand, Mignon-Grasteau (1999) found that the maturation rate was large for females compared with males based on the Gompertz growth model, this result is in line with those obtained for MXLC using the same model.

The relative growth and exponential growth rate predicted in this research were close to the values reported by Rizzi et al. (2013) in local Italian chickens using Logistic model and Narinc et al. (2010) in slow-growing broilers using the Von Bertalanffy model. Nevertheless, were lower comparing to those obtained from fast-growing chickens (Ross PM3) reported by Topal and Bolukbasi (2008) (females = 0.781 and males = 0.744).

The fact that relative growth is low in MXLC compared to the fast-growing chickens is explained by the lack of a genetic improvement program.

Age of maximum growth predicted by the Logistic model for MXLC is in agreement with that reported by Osei-Amponsah et al. (2014) in Ghanaian local chickens and Yang et al. (2006) in Jinghai yellow chickens. On the other hand, Aggrey (2002) reported lower values for age of maximum growth in unselected female using the Gompertz-Laird, Logistic and Richards models. This finding confirms that males reach the age of maximum growth later than females. The weights at the point of inflection predicted by the Von Bertalanffy model were 596.0 g for females and 892.2 g for males. However, Zhao et al. (2015) indicate that indigenous chicken in China had lower values for weight at inflection point using the same model.

In general, the males had greater asymptotic weight than the females for all the models. In a study conducted in Spain with Castellana Negra male chickens, Miguel et al. (2008) estimated an asymptotic weight of 2,660.9 g using the Gompertz model, this result is close to what was found in this research for MXLC males (2,683.1 g). Additionally, Rizzi et al. (2013) reported an asymptotic weight of (2,046.0 g) female Italian local chickens using Richards model, which is in accordance with what was found for MXLC females (2,012.8 g).

In line with our results, Yang et al. (2006), Ngeno et al. (2010) and Adenaike et al., 2017 produced the best fitting of the data for LC. On the other hand, Rizzi et al., 2013 and Osei-Amponsah et al. (2014) found that Richards model was best-fitted model for describing growth the local chickens.

While, Zhao et al. (2015) found that Gompertz model was the best one to describe growth pattern of Chinese indigenous chicken.

In conclusion, based on the goodness of fit criteria (R^2, AIC, BIC), the best fit of the data was obtained with the Von Bertalanffy model for both sexes. Knowledge about the growth characteristics for each sex of the MXLC could help to define feeding programs to meet the nutritional needs from hatching to age of maximum growth, reproduction programs and marketing strategies. The information generated in this research is essential to development a program for the utilization of MXLC under the natural environmental conditions of Campeche State, Mexico. Finally, it is recommended to do more research to estimate genetic parameters of the elements in growth models of MXLC, this would allow to take decisions of selection based on the growth characteristics.

2.6. ACKNOWLEDGMENT

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CONCLUSIONES GENERALES

Los pollos de traspatio son una fuente de proteína animal e ingreso económico para las familias rurales del estado de Campeche, México.

La inadecuada alimentación, enfermedades, depredadores y falta de asistencia técnica son los principales factores que limitan la producción de los pollos de traspatio en el estado de Campeche, México.

El mejor modelo que se ajustó a los datos de pesos corporales para ambos sexos de los pollos de traspatio fue el Von Bertalanffy, el modelo mostró que las hembras alcanzan la madurez en edades más precoces, mientras que los machos presentan peso adulto más elevado.