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Changes in the hematology and blood metabolites of guinea pigs (*Cavia porcellus*) under intensive rearing system in humid tropical conditions

Cambios relacionados con la edad en la hematología y metabolitos sanguíneos de cuyes (*Cavia porcellus*) en sistema de crianza intensivo en condiciones de trópico húmedo

Daniel Paredes-López*[1], Rizal Robles-Huaynate[1], Uriel Aldava-Pardave[2] and Miguel Morales-Cauti[3]

[1]*Departamento de Ciencia Animal, Universidad Nacional Agraria de la Selva, Carretera Central Km 1.21, Tingo María, Perú.*
[2]*Escuela de posgrado, Universidad Nacional Agraria La Molina, Av. La molina s/n La Molina, Lima, Perú.*
[3]*Departamento de Salud Animal y Salud Pública, Facultad de Medicina Veterinaria, Universidad Nacional Mayor de San Marcos, Av. Circunvalación s/n, San Borja, Lima, Perú.*

*Corresponding author: daniel.paredes@unas.edu.pe

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Abstract

Guinea pigs in intensive production generates an imperative necessity of physio-pathological bases for diagnosing their state of welfare, health, and production; those which are available for this species are referred to as laboratory or companion animal. The aim of this research is to determine changes in hematological and blood metabolites profiles in relation to age of Cavia porcellus reared in intensive system at 660 masl in humid tropic. For this purpose, forty 15-120 days old guinea pig in healthy conditions from the inti x Peru lines born in the humid tropic were used and the evaluation ages were 15-21, 22-35, 36-60 and 61-120 days. Blood samples were obtained by puncture of the cephalic vein; profiles of erythrocytes (RBC), total leucocytes (WBC), lymphocytes, granulocytes, hematocrit, hemoglobin, MCV, MCH and MCHC indices were determined. In serum, profiles of glucose, total protein (TP), albumin, total cholesterol (TC), triglycerides, total bilirubin (TB), and direct bilirubin (DB), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were determined. Hemoglobin profile, MCH and MCHC indices increased as age increased ($p < 0{,}05$) and the erythrocytes, leucocytes, hematocrit, hemoglobin profiles and MCV, MCH, MCHC indices showed the narrower interval ranges in the 15-35- and 61-120-days old guinea pigs. Profiles of TP, DB and AST showed increase with age ($p < 0{,}05$) and the DB, AST, ALT, and TC profiles showed the narrower interval range at 36-120 days old. The hematological and blood metabolites profiles of guinea pigs raised in intensive system in humid tropical conditions show significant changes with production age.

Keywords: Welfare, guinea pigs, rearing system, hematology, intensive production

Resumen

Los cuyes en producción intensiva generan la necesidad de bases fisiopatológicas para diagnosticar su estado de bienestar, salud y producción; las disponibles están referidas a esta especie como animal de laboratorio o de compañía. El objetivo de esta investigación es determinar los perfiles hematológicos y metabolitos sanguíneos en relación con la etapa de producción de cuyes en sistema de crianza intensivo a 660 msnm en trópico húmedo. Cuarenta cuyes clínicamente sanos de las líneas inti x Perú nacidos en trópico de 15-120 días de edad se distribuyeron en cuatro grupos etarios: 15-21, 22-35, 36-60 y 60-120 días. En sangre se determinó los perfiles de eritrocitos, leucocitos, linfocitos, granulocitos, hematocrito y hemoglobina e índices de MCV, MCH y MCHC y en suero sanguíneo los perfiles de glucosa, proteína total (PT), albumina, colesterol total (CT), triglicéridos, ALT, AST y bilirrubina directa (BD). El perfil de hemoglobina y los índices de MCH y MCHC incrementaron con la edad ($p < 0,05$) y los perfiles de eritrocitos, leucocitos, hemoglobina y hematocrito y los índices de MCV, MCH, MCHC mostraron una menor amplitud de intervalos en los cuyes de 15-35 y 61-120 días de edad. Los perfiles de PT, BD y AST incrementaron con la edad ($p < 0,05$) y los perfiles de BD, AST, ALT y CT mostraron la menor amplitud de intervalo entre los 36-120 días de edad. Los perfiles hematológicos y de metabolitos sanguíneos en los cuyes criados en sistema de crianza intensivo en condiciones de trópico húmedos muestran cambios significativos con la edad de producción.

Palabras clave: Bienestar, cuy, sistema de crianza, hematología, producción intensiva.

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Orcid IDs:

Daniel Paredes-López: https://orcid.org/0000-0002-0266-7138
Rizal Alcides Robles-Huaynate: https://orcid.org/0000-0001-8013-2481
Uriel Aldava-Pardave: https://orcid.org/0000-0001-8298-5445
Miguel Morales-Cauti: https://orcid.org/0000-0002-5396-8889

1 Introduction

The guinea pig (*Cavia porcellus* L.) is an animal that originates in the South American Andes; the breeding in Peru mainly occurs in the Andean regions, the coast (Yamada et al., 2019) and recently in the Amazon region, characterized and reared as a meat producing animal with high nutritional value. Guinea pigs have been bred in the Andes at altitudes of more than 3800 masl for thousands of years, under extreme cold and hypoxia conditions; likewise, at sea level under temperate and normoxia conditions (Lechner et al., 1981, 1980b), having adapted similarly to other animal species (Ding et al., 2014; Al-Sweedan and Alhaj, 2012; Snyder et al., 1982)(Ding et al., 2014; Al-Sweedan and Alhaj, 2012; Snyder et al., 1982).

In Peru, breeding of guinea pigs was originally oriented to self-consumption and food security, generating additional income from the sale of the remnant and more opportunity in the workforce, mainly for women in rural areas (Chauca, 1995). However, it tends to move towards developing into an intensive production (Olazábal et al., 2019; Yamada et al., 2019), generating an increase in the development of pathologies in the specie (Venturo and Morales-Cauti, 2020; Barrios-Arpi and Morales-Cauti, 2020; Bazán et al., 2019; Paredes-López et al., 2014; Layme et al., 2011); hence, in order to control these pathologies, it is necessary to develop physiopathological bases for diagnosing their health and production.

These conditions, along to those changes in climate and food factors, could lead to adaptive physiological variations and among them, one of the most sensitive is what occurs in blood. In preventative medicine, physiological changes in blood are part of minimum database for any animal species, with the purpose of interpreting its state of health or disease and production (Ramirez-Borda et al., 2019; Luna et al., 2018; Izurieta et al., 2017; Gupta et al., 1999).

In many animal species used for production, as is the guinea pig, normal reference hematological and blood metabolites profiles and their intervals are not available, and those which are available are referred to the guinea pig as laboratory animal (McClure, 1999; Dyer and Cervasio, 2008; Hoffman and Solter, 2008; Zimmerman et al., 2010; Washington and Van Hoosier, 2012; Zimmerman et al., 2015; Alberton et al., 2019). Therein, obtaining the blood profiles of guinea pigs during the different stages of intensive rearing, in a normal state of health under humid tropical conditions, would contribute to defining the changes in the blood markers and indicators, according to the age, for the purposes of diagnosing the health and production state of this animal species (Lewis, 1992; Doneley, 2015).

The aim of this paper is to study the changes in hematological and blood metabolites profiles at different production ages of guinea pigs in an intensive rearing system under humid tropical conditions.

2 Materials and Methods

2.1 Area of research

The study was carried out on the zootechnics farm at the Universidad Nacional Agraria de la Selva, Tingo María, Peru, located at 09°17′58″S latitude and 76°01′07″ W longitude, with an altitude of 660 masl, presenting an annual pluvial precipitation of 3293 mm, an average annual temperature of 24.85°*C*, a relative humidity of 80% during the season of least precipitation (June-September) and 85% during the greatest precipitation season (October-May) (Servicio Nacional de Meteorología e Hidrología (SENAMHI), 2021). This study was carried out from October to December.

2.2 Animals Studied

Forty guinea pigs from 15-120 days' old obtained from inti x Peru lines adapted to humid tropic for two years were used. The evaluation phases were at 15 – 21 days old (initial), 22 – 35 days (growth), 36 – 60 days (finishing) and 60 – 120 days old (adults).

Four groups were formed and each one was composed of ten guinea pigs that were placed in separate cages, administering a daily diet of King Grass as *ad libitum* forage and a balanced diet for guinea pigs, according to their production phase (Vergara, 2009). Each group or production phase was independent from the other.

2.3 Immobilization and Blood Sampling

The guinea pigs were taken from below the body trunk with one hand and supported below the hindquarters with the other hand, trying not compress the thorax or abdomen. The skin was shaved and alcohol was applied for disinfecting and to visualize the cephalic vein, and the blood samples were obtained by puncturing it (Dyer and Cervasio, 2008; Quesenberry et al., 2012).

All the blood was obtained in vacutainers containing 2 mg of EDTA. In order to obtain the serum, the blood was put into clean vials and left to coagulate for 1 – 2 hours and then was centrifuged at 1500 rpm for three minutes; later the serum was separated into vacutainers to preserve it at $-20°C$. Ten whole blood samples and ten blood for serum samples were drawn from each of the groups in the phases 15– 21, 22– 35, 36– 60 and 61– 120 days old.

2.4 Hematological assessment and blood metabolites profile

In the whole blood, the number of erythrocytes (ER), leukocytes (LE), lymphocytes (Ly), and granulocytes (Gra) were determined using the Neubauer and Wright-Giemsa techniques (Harvey, 2001) and the hematocrit (Ht) was determined using the microhematocrit technique at 11,000 rpm in a Kert Lab Tom's centrifuge (USA Science Tech Group); the hemoglobin (Hb) was determined using the cyanmethemoglobin method and quantified using a 405 to 530 nm DIALAB DTN spectrophotometer. Mean cell volume (MCV), mean cell hemoglobin (MCH) and mean cell hemoglobin concentration (MCHC) indices were determined (Samour et al., 2016; Doneley, 2015).

In the blood serum, the glucose level was determined through the glucose oxidase-peroxidase method; the total protein, using the complex EDTA/Cu method in sodium hydroxide; the albumin, using the tetrabromide phenolsulfonphthalein method; the total cholesterol, alanine transaminase, aspartate transaminase, total bilirubin, and conjugated bilirubin (Laboratorios QAC, Espain). The measurements were done using a DIALAB DTN 405 to 515 and 530 nm spectrophotometer.

2.5 Statistical Analysis

The average values and the standard deviation were calculated from the data obtained, and later the ANOVA was done; in a previous step the assumption of the sphericity between the measurements was verified using Mauchly's test. The multiple comparisons test was done using the Bonferroni test; in a previous step the assumption of normality test was done for each measurement using the Shapiro-Wilk test. The Infostat statistical software was used. The differences at $p \leq 0{,}05$ were significant.

3 Results and discussion

Most of the studies regarding hematology and blood metabolites profiles in *Cavia porcellus* that are found in scientific literature refer to studies as an experimental specie in laboratory, but not as a specie for meat production purpose, and particularly under intensive rearing systems (Paredes-López et al., 2017; Ramirez-Borda et al., 2019). As a laboratory animal, many strains or biotypes of guinea pigs have been obtained, and characteristics of sensibility have been found for different aspects of one specific disease or another (Waner et al., 1996; Kitagaki et al., 2005; Genzer et al., 2019).

Profiles of red blood cells, hemoglobin, hematocrit, MCV, MCHC, MCH indices, white blood cells, granulocytes and lymphocytes percentage for guinea pigs under an intensive rearing system in tropic humid conditions were evaluated at 15-120 days old (Tables 1 and 2). The hemoglobin profiles and MCH and CMCH indices in 61–120 days old guinea pigs show higher levels than the 15–35 days old ($p < 0{,}05$); but like the 35-60 days old guinea pigs for the MCHC and MCH indices ($p > 0{,}05$). Nonetheless, the hematocrit and red blood cell profiles in the 22–35 days old guinea pigs were lower than those obtained for the 15–21 and 61–120 days old ($p < 0{,}05$), but equal to those for the 36 – 60 days old guinea pigs ($p > 0{,}05$) (Table 1).

Table 1. Hematological profiles of guinea pigs 15-120 days old under intensive rearing system in humid tropical conditions (95 % CI).

			Age (days)			
Hematological Profiles	**p-values**	**CV (%)**	**15-21** $\bar{x} \pm SE$	**22-35** $\bar{x} \pm SE$	**36-60** $\bar{x} \pm SE$	**61-120** $\bar{x} \pm SE$
HCT (%)	0.004	9.26	37.00 ± 0.49^{a}	32.10 ± 0.97^{b}	33.60 ± 1.61^{ab}	36.40 ± 0.60^{a}
Hgb (gdL^{-1})	0.000	10.49	11.88 ± 0.30^{c}	11.04 ± 0.22^{c}	13.73 ± 0.74^{b}	15.65 ± 0.27^{ba}
WBC ($\times 10^3$)	0.000	17.94	3.38 ± 0.13^{b}	5.74 ± 0.25^{a}	3.08 ± 0.31^{b}	3.47 ± 0.15^{b}
RBC ($\times 10^6$)	0.003	9.62	4.03 ± 0.06^{a}	3.43 ± 0.11^{b}	3.70 ± 0.18^{ab}	3.93 ± 0.07^{a}
MCHC (gdL^{-1})	0.000	10.06	32.11 ± 0.73^{b}	34.53 ± 0.68^{b}	41.23 ± 1.92^{a}	43.10 ± 1.04^{a}
MCH (pg)	0.000	8.86	29.44 ± 0.64^{b}	32.30 ± 0.65^{b}	37.48 ± 1.73^{a}	39.97 ± 0.93^{a}
MCV (fl)	0.169	3.08	91.76 ± 0.56^{a}	93.69 ± 1.54^{a}	90.91 ± 0.00^{a}	92.70 ± 0.74^{a}
GRAN (%)	0.000	33.12	31.30 ± 4.48^{b}	29.80 ± 3.28^{b}	22.20 ± 1.40^{b}	46.30 ± 4.02^{a}
LYM (%)	0.001	16.95	65.10 ± 4.07^{ab}	68.50 ± 3.47^{a}	74.50 ± 1.99^{a}	52.80 ± 4.04^{b}

CV: variation coefficient; abc: Different letters within each variable express significant differences with a 95
$\bar{x}$: arithmetic average; *SE*: standard error; HCT: hematocrit, Hgb: hemoglobin, WBC: leukocytes (white blood cells), RBC: red blood cells, MCHC: mean corpuscular hemoglobin concentration, MCH: mean corpuscular hemoglobin, MCV: mean corpuscular volume, GRAN: granulocytes.

The erythrocyte profiles obtained in this study in local guinea pigs with differences in genetics, nutrition, and breeding purposes, follow similar tendencies of those for established references of strains or biotypes of laboratory guinea pigs (Zimmerman et al., 2010; McClure, 1999) the 13/N strain (Genzer et al., 2019), Dunkin-Hartley (Waner et al., 1996), Weiser-Maples (Kitagaki et al., 2005). Nonetheless, these profiles are much lower than those obtained from guinea pigs reared in environments of hypoxia (pO_2:80 Torr) and a temperature of $22°C$ (Lechner et al., 1980a), an environment of hypoxia (pO_2:85 Torr) and a temperature of $6°C$; conditions similar to those at more than 4000 masl (Lechner et al., 1981), in which the erythrocyte profiles increased between 13 and 42%, with respect to the referential levels, as well as being lower than the erythrocyte profiles obtained from guinea pigs in normal oxygen environments (pO_2=133 Torr) and a temperature of $5°C$ (Lechner et al., 1980c).

The highest red blood cell profiles showed in guinea pigs reared in an environment of hypoxia rather than those in environments of normoxia, as in the current study, relates to the fact that the low oxygen pressure stimulates an increase in the erythropoietin levels, which at the same time stimulates the erythropoiesis as a compensation mechanism for reestablishing the levels of the oxygen pressure in an organism (Reece, 2015).

In this study it was showed that the hematocrit levels and number of erythrocytes varied with the age or physiological state ($p < 0{,}05$). It is worth noting that the hematocrit and the erythrocytes reduced in the 21-35 days old and reestablished their levels in the 61–120 days old guinea pigs, which is similar to those reported by Lechner et al. (1980b). Different tendencies have been reported in guinea pigs of the 13/N strain, in which these parameters increased with age within a six-month period. Notwithstanding, the hemoglobin, MCH and MCHC levels increased with the age of the guinea pigs in the present study ($p < 0{,}05$), and these were evident in the 36–120 days old. The results contrast with those obtained in the 13/N strain, in which the levels of these profiles were greater in younger guinea pigs than in adults (Genzer et al., 2019), as well as the results reported by Lechner et al. (1980a).

The white blood cell and lymphocyte profiles in the 22–35 days old guinea pigs showed greater levels than those presented in the 15–21 and 61-120 days old ($p < 0{,}05$), notwithstanding, the granulocytes profile was greater in the 61–120 days old than that found for 15-60 days old of production ($p < 0{,}05$).

The withe blood cells profile reached a peak in the 22–35 days old, declining and staying steady at the same level in the 36–120 days old guinea pig. The lymphocytes and granulocytes did not vary in

the 15- 60 days old guinea pigs; later the lymphocytes reduced and the granulocytes increased in the 61–120 days old. Similar tendencies were shown in strain 13/N guinea pigs for the leukocytes and lymphocytes, nonetheless, it was different for the granulocytes, for which the neutrophils also diminished with age (Genzer et al., 2019).

Reference amplitude intervals were established to each of the guinea pig's production phase for these hematologic profiles. These intervals of the means showed different amplitudes in the four production phases and within these, the means of granulocytes and lymphocytes in the 15–21, 61–120 and 22–35 days old guinea pigs show from the greatest to the least, the higher amplitude. On the other hand, the means of RBC, WBC, hemoglobin and hematocrit profiles and the MCV, MCH and MCHC indices, in the15–21, 22–35 and 61–120 days old guinea pigs show from least to greatest, the lesser amplitude (Table 2).

Publications referring to intervals of hematologic profiles by production phases of guinea pigs are not found, nonetheless, the intervals found in this research follow similar tendencies to those reported as established reference intervals for experimental guinea pigs in laboratory (Zimmerman et al., 2015; Quesenberry et al., 2012; McClure, 1999); strain 13/N (Genzer et al., 2019), Weiser-Maples (Kitagaki et al., 2005).

Table 2. Means amplitude intervals for the hematologic profiles of 15-120 days old guinea pigs under intensive rearing system in humid tropical conditions (95 % CI).

Hematologic Profiles	**Age (days)**			
	15-21	**22-35**	**36-60**	**61-120**
Hto (%)	[35.88 – 38.12]	[29.90 – 34.30]	[29.95 – 37.25]	[35.04 – 37.76]
Hb (gdL^{-1})	[11.19 – 12.56]	[10.54 – 11.54]	[12.06 – 15.39]	[15.05 – 16.25]
WBC ($\times 10^3$)	[03.08 – 03.68]	[05.17 – 06.30]	[02.38 – 03.77]	[03.13 – 03.81]
RBC ($\times 10^6$)	[03.90 – 04.17]	[03.18 – 03.68]	[03.29 – 04.10]	[03.29 – 04.10]
MCHC (gdL^{-1})	[30.47 – 33.75]	[32.99 – 36.07]	[36.88 – 45.59]	[40.76 – 45.45]
MCH (pg)	[28.09 – 30.80]	[31.04 – 33.56]	[33.53 – 41.45]	[37.57 – 42.36]
MCV (fl)	[90.49 – 93.02]	[90.20 – 97.17]	[90.91 – 90.91]	[91.03 – 94.38]
Gra (%)	[21.16 – 41.44]	[22.37 – 37.23]	[19.04 – 25.36]	[41.21 – 59.39]
Ly (%)	[55.89 – 74.31]	[60.65 – 76.35]	[70.00 – 79.00]	[46.67 – 61.93]

Hto: hematocrit, Hb: hemoglobin, WBC: white blood cells, RBC: red blood cells, Gra: granulocytes, Ly: lymphocytes, MCHC: mean corpuscular hemoglobin concentration,
MCH: mean corpuscular hemoglobin, MCV: mean corpuscular volume.

The profiles and intervals of blood metabolites in the guinea pigs at 15–120 days old are shown in table 3 and 4. The total bilirubin and urea profiles showed greater levels in 61–120 days old compared to 15–60 days old guinea pigs ($p < 0{,}05$). Similarly, the total protein, BD and AST profiles showed greater levels in the 36–120 days old guinea pigs than in the 15–35 ($p < 0{,}05$) days old. Glucose and triglycerides profiles decreased in the 22-35 days old and then they reestablished in the 36-120 days old guinea pigs ($p < 0{,}05$).

The ALT profile was greater in the 22–35 days old guinea pigs compared to the 15-21 and 36-120 days old ($p < 0{,}05$). On the other hand, the total cholesterol profile was higher in the 15-21 days old than in the 22-120 days old guinea pigs ($p < 0{,}05$) (Table 3).

The blood metabolites profiles obtained in this study as the hematological profiles, follow similar tendencies than those established in strains and biotypes of experimental guinea pigs in laboratories (Washington and Van Hoosier, 2012; Zimmerman et al., 2010; McClure, 1999), strain 13/N (Genzer et al., 2019), Dunkin-Hartley (Waner et al., 1996), Weiser-Maples (Kitagaki et al., 2005); improved criollo (Paredes-López et al., 2017; Ramirez-Borda et al., 2019).

Table 3. Blood metabolites profiles of 15-120 days old guinea pigs under intensive rearing system in humid tropical conditions (95 % CI).

			Age (days)			
Blood metabolite Profile	**p-value**	**CV (%)**	**15-21** $\bar{x} \pm SE$	**22-35** $\bar{x} \pm SE$	**36-60** $\bar{x} \pm SE$	**61-120** $\bar{x} \pm SE$
TP (gdL^{-1})	0.000	9.50	6.78 ± 0.25^{c}	6.89 ± 0.33^{bc}	7.73 ± 0.14^{ab}	8.22 ± 0.10^{a}
AL (gdL^{-1})	0.001	8.32	3.94 ± 0.04^{ab}	3.57 ± 0.15^{bc}	3.50 ± 0.11^{c}	4.04 ± 0.05^{a}
TB ($mgdL^{-1}$)	0.000	14.20	0.58 ± 0.02^{c}	0.55 ± 0.02^{c}	0.71 ± 0.06^{b}	0.92 ± 0.02^{a}
DB ($mgdL^{-1}$)	0.001	18.91	0.15 ± 0.01^{b}	0.15 ± 0.01^{b}	0.20 ± 0.01^{a}	0.20 ± 0.01^{a}
Glucose($mgdL^{-1}$)	0.000	11.09	86.22 ± 4.80^{a}	59.55 ± 2.62^{b}	87.23 ± 0.71^{a}	86.00 ± 0.93^{a}
TC ($mgdL^{-1}$)	0.000	11.56	71.64 ± 2.70^{a}	47.28 ± 1.55^{b}	27.64 ± 0.66^{c}	28.49 ± 0.34^{c}
TG ($mgdL^{-1}$)	0.024	31.95	58.08 ± 9.11^{a}	37.17 ± 1.43^{b}	44.57 ± 0.70^{ab}	44.14 ± 0.93^{ab}
AST (UIL^{-1})	0.000	4.90	61.19 ± 0.81^{c}	81.63 ± 2.24^{b}	89.39 ± 0.72^{a}	91.32 ± 0.26^{a}
ALT (UIL^{-1})	0.000	6.93	11.34 ± 0.19^{c}	20.30 ± 0.49^{a}	16.41 ± 0.36^{b}	12.19 ± 0.16^{c}
Urea ($mgdL^{-1}$)	0.000	11.61	37.70 ± 1.95^{b}	34.06 ± 1.38^{b}	35.55 ± 0.81^{b}	45.63 ± 1.24^{a}

CV: Variation Coefficient; abc: Different letters in each row express significant differences with a 95
TP: total protein, AL: albumin, TB: total bilirubin, DB: direct bilirubin, TC: total cholesterol, TG: triglycerides, AST: aspartate transaminase, ALT: alanine transaminase.

The total protein, total bilirubin, direct bilirubin, AST and urea profiles show a tendency to increase with age, showing greater levels between 61–120 days old. These results are supported by physiological mechanisms which make that total protein, albumin, and globulins in serum of all animal species increase as they are getting to the adult phase (Eckersall, 2008).

The total protein and urea profiles are like those reported by Genzer et al. (2019) and (Kitagaki et al., 2005) in Weisser-Maple guinea pigs; studies in which it was show that the profiles of these metabolites are correlated with the age of the guinea pigs. The AST and albumin profiles are different to those found in those studies and as for the total bilirubin profiles, it does not correlate with the age of the guinea pigs.

On the other hand, the TC profiles markedly reduced as age increased, showing the highest levels between 15 – 21 days of age, which contrasts with the results showed by Kitagaki et al. (2005) in Weisser-Maple guinea pigs, in which this metabolite increased in a gradual and continuous form as the age increased.

The glucose, triglyceride and ALT profiles showed homogenous levels in the different stages of age, with similar results to those reported by Genzer et al. (2019) and Kitagaki et al. (2005) in Weisser-Maple guinea pigs, which have also shown that the levels of these metabolites are not correlated with the age of the guinea pigs. Nonetheless, in the 22–35 days old, glucose and triglycerides markedly reduced, and the ALT increased, and these metabolites reestablished in the 36-120 days old guinea pigs. The variations of these metabolites in this stage could be due to diminishing energy reserves by suppression of easily degraded carbohydrates due to weaning, thus lowering the glucose levels and accelerating the growth of different tissues, and above all, the hepatic tissue, for metabolizing more complex components that come from their new diet, generating an increase in the ALT profiles (Hoffman and Solter, 2008).

The means intervals of the different blood profiles were observed in the 15–35 days old guinea pigs and within them, triglycerides, total bilirubin, glucose, urea and protein showed the greatest amplitude in intervals, from greatest to least, respectively. On the other hand, in the 36–120 days old guinea pigs, intervals of lesser amplitude were found and the direct bilirubin, AST, ALT and TC profiles showed the least amplitudes, from least to greatest, respectively (Table 4).

Table 4. Means amplitude intervals for blood metabolites profiles of 15-120 days old guinea pigs under intensive rearing system in humid tropical conditions (95 % CI).

Blood metabolite profile	Age (days)			
	15-21	**22-35**	**36-60**	**61-120**
TP (gdL^{-1})	[06.22–07.34]	[06.15–07.64]	[07.42–08.04]	[07.98–08.46]
AL (gdL^{-1})	[03.85–04.02]	[03.22–03.91]	[03.25–03.75]	[03.93–04.14]
TB ($mgdL^{-1}$)	[00.54–00.62]	[00.51–00.58]	[00.58–00.83]	[00.89–00.95]
DBIL ($mgdL^{-1}$)	[00.14–00.17]	[00.12–00.18]	[00.17–00.23]	[00.18–00.21]
Glucose(gdL^{-1})	[75.36–97.08]	[53.64–65.47]	[85.61–88.84]	[83.90–88.10]
TC ($mgdL^{-1}$)	[65.74–77.74]	[43.77–50.79]	[26.15–29.14]	[27.72–29.26]
TG ($mgdL^{-1}$)	[43.56–54.93]	[33.52–40.90]	[42.68–46.27]	[41.69–46.46]
AST (UIL^{-1})	[59.36–63.03]	[76.57–86.70]	[87.75–91.03]	[90.72–91.91]
ALT (UIL^{-1})	[10.90–11.77]	[19.19–21.41]	[15.59–17.24]	[11.82–12.56]
Urea ($mgdL^{-1}$)	[33.29 – 42.11]	[30.95–37.18]	[33.72–37.38]	[42.84–48.43]

TP: total protein, AL: albumin, TB: total bilirubin, DBIL: direct or conjugated bilirubin, TC: total cholesterol, TG: triglycerides, AST: aspartate transaminase, ALT: alanine transaminase.

Similarly to the intervals for the hematological profiles, publications referring to intervals of blood metabolites profiles by development phase in guinea pigs for production are not found, nonetheless, the mean amplitude intervals found in this research follow similar tendencies to those reported as reference intervals established for laboratory guinea pigs (Quesenberry et al., 2012; McClure, 1999; Ness, 1999; Washington and Van Hoosier, 2012; Williams et al., 2016); strain 13/N (Genzer et al., 2019), Weiser-Maples (Kitagaki et al., 2005).

In guinea pigs for production, due to elevated metabolic needs in order to respond to the pressure for production, the hematological and blood metabolites physiology varies in short periods of age or stages, contrasting with guinea pigs with the purpose of being laboratory animals, and thus it is useful to have profiles and their mean amplitude intervals for these profiles in order to interpret the state of health and production of this animal species more adequately.

The profiles and mean amplitude intervals of the hematologic and blood metabolites profiles obtained in this study, despite the genetic differences, nutrition, and purpose for breeding, differ only slightly from those obtained in the strains or biotypes of guinea pigs for laboratory experiments.

4 Conclusions

The hematologic and blood metabolites profiles obtained from the guinea pigs raised under intensive breeding systems in humid tropical conditions show significant changes with their age of production.

These profiles are close to those reported for guinea pigs used as laboratory animals, raised in environments of normoxia and the hematological profiles are inferior to those reported for the guinea pigs raised in environments of hypoxia, nonetheless, studies in endocrine biochemistry should be carried out with the aim of contributing to the improvements of the welfare, health, and production of this specie.

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Author contribution

D.P.L.: Conceptualization, project administration, methodology, original draft writing; R.R.H.: Formal analysis, investigation, validation, visualization; U.A.P.: Data curation, resources, software;

M.M.C.: Funding acquisition, supervision, writing-review and editing.

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