UNIVERSIDADE ESTADUAL PAULISTA - UNESP

CÂMPUS DE JABOTICABAL

QUALIDADE MUSCULOESQUELÉTICA E VISCERAL DE FRANGOS DE CORTE DE DIFERENTES PADRÕES CORPORAIS

Juciê Leite dos Santos

Médico Veterinário

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Orientadora: Profa. Dra. Lizandra Amoroso

Dissertação apresentada à Faculdade de Ciências Agrárias e Veterinárias – Unesp, Câmpus de Jaboticabal, como parte das exigências para a obtenção do título de Mestre em Ciências Veterinárias.

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Câmpus de Jaboticabal

CERTIFICADO DE APROVAÇÃO

TÍTULO DA DISSERTAÇÃO: QUALIDADE MUSCULOESQUELÉTICA E VISCERAL DE FRANGOS DE CORTE DE DIFERENTES PADRÕES CORPORAIS

AUTOR: JUCIÊ LEITE DOS SANTOS
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Jaboticabal, 20 de julho de 2023

DADOS CURRICULARES DO AUTOR

Juciê Leite dos Santos nascido na cidade de Lago do Junco – MA, em 30 de julho de 1995. Formado em Medicina Veterinária (Bacharelado) pela Universidade Estadual da Região Tocantina do Maranhão – UEMASUL, Imperatriz, Maranhão, no ano de 2021. Durante a graduação realizou estágio curricular no Hospital Veterinário Universitário "Francisco Edilberto Uchoa Lopes", na cidade de São Luís – MA. E, na clínica de cães e gatos e laboratório da SERVET, em Imperatriz – MA. Na graduação participou como bolsista voluntário de iniciação científica desenvolvendo pesquisas com pequenos ruminantes da região Tocantina. Apresentou trabalhos em congressos estaduais, nacionais e internacionais. Além disso, participou de conferências e workshops relevantes para a área de estudo, buscando aprimorar habilidades de pesquisa e expandir a rede de contatos. Finalizando o Mestrado em Ciências Veterinárias em 2023.

Epígrafe

“Eis meu segredo. É muito simples: Só se vê bem com o coração, o essencial é invisível aos olhos”

(Antoine de Saint-Exupéry)

DEDICATÓRIA

Dedico este trabalho à Marta, minha mãe, inspiração e fonte inesgotável de força e amor. Ao meu amado pai, Alcione (*in memorian)*, que continua vivo em mim. Às minhas irmãs Raquel e Rayane que sempre estiveram comigo .

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O presente trabalho foi realizado com apoio da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Código de Financiamento 001.

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unesp UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO" Câmpus de Jaboticabal

CEUA – COMISSÃO DE ÉTICA NO USO DE ANIMAIS

CERTIFICADO

Certificamos que o projeto intitulado "**Escore corporal e qualidade musculoesquelética e visceral das aves de corte**", protocolo nº 3689/21, sob a responsabilidade da Profa. Dra. Lizandra Amoroso, que envolve a produção, manutenção e/ou utilização de animais pertencentes ao Filo Chordata, subfilo Vertebrata (exceto o homem), para fins de pesquisa científica (ou ensino) - encontra-se de acordo com os preceitos da lei nº 11.794, de 08 de outubro de 2008, no decreto 6.899, de 15 de julho de 2009, e com as normas editadas pelo Conselho Nacional de Controle de Experimentação Animal (CONCEA), e foi aprovado pela COMISSÃO DE ÉTICA NO USO DE ANIMAIS (CEUA), da FACULDADE DE CIÊNCIAS AGRÁRIAS E VETERINÁRIAS, UNESP - CÂMPUS DE JABOTICABAL-SP, em reunião ordinária de 16 de dezembro de 2021.

Vigência do Projeto	10/01/2022 a 31/12/2022
Espécie / Linhagem	Aves comerciais Cobb 500 e Ross
Nº de animais	72
Peso / Idade	Não e aplica / 42 dias
Sexo	Machos e fêmeas
Origem	Abatedouro de Nuporanga - SP

Jaboticabal, 16 de dezembro de 2021.

Fabiana Pilarski

Profa. Dra. Fabiana Pilarski
Coordenadora – CEUA

Faculdade de Ciências Agrárias e Veterinárias
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QUALIDADE MUSCULOESQUELÉTICA E VISCERAL DE FRANGOS DE CORTE DE DIFERENTES PADRÕES CORPORAIS

RESUMO - O Brasil é o principal exportador de carne de frango. O alimento é amplamente consumido no país devido o preço acessível, facilidade de preparo, variedade de produtos e valor nutricional. A busca por maior qualidade impulsiona inovações tecnológicas na avaliação e produção desses alimentos. No entanto, a avicultura enfrenta desafios, como o desenvolvimento inadequado dos frangos e a desuniformidade nos lotes, resultando em condenações no abate devido a problemas de saúde. A regulamentação, como o Serviço de Inspeção Federal (SIF), define critérios para abate e condenação de carcaças com alterações. A tipificação de carcaças é influenciada por vários fatores, como genética, manejo e nutrição. A caquexia é uma das principais causas de condenações pós-morte, resultando em prejuízos econômicos. A avaliação morfológica de frangos de corte é importante para compreender a conformação da carcaça e suas correlações com características dos órgãos internos. Supõe-se que os frangos de corte desuniformes podem ser aproveitados na indústria para reduzir perdas econômicas nos abatedouros. O objetivo da pesquisa foi analisar os aspectos estruturais de diferentes padrões de frangos de corte e verificar a possibilidade de aves desuniformes serem aproveitadas para reduzir perdas econômicas no abate.

Palavras-chave: avicultura comercial, produção, saúde, uniformidade de lotes

MUSCULOSKELETAL AND VISCERAL QUALITY OF BROILER CHICKENS OF DIFFERENT BODY PATTERNS

ABSTRACT - Brazil is the main exporter of chicken meat. The food is widely consumed in the country due to its affordable price, ease of preparation, variety of products and nutritional value. The search for higher quality drives technological innovations in the evaluation and production of these foods. However, poultry farming faces challenges, such as inadequate chicken development and non-uniformity in batches, resulting in slaughter condemnations due to health problems. Regulations, such as the Federal Inspection Service (SIF), define criteria for the slaughter and condemnation of carcasses with injuries. Carcass typing is influenced by several factors, such as genetics, management and nutrition. Cachexia is one of the main causes of postmortem convictions, resulting in economic losses. The morphological evaluation of broiler chickens is important to understand carcass conformation and its correlations with internal organ characteristics. It is assumed that uneven broilers can be used in the industry to reduce economic losses in slaughterhouses. The objective of the research was to analyze the structural aspects of different patterns of broiler chickens and verify the possibility of uneven birds being used to reduce economic losses at slaughter.

Keywords: commercial poultry farming, production, health, batch uniformity

CAPÍTULO 1

CAPÍTULO 1- Considerações gerais

1. INTRODUÇÃO

O Brasil é o maior exportador de carne de frango do mundo e, um dos maiores produtores. De acordo com a Associação Brasileira de Proteína Animal (ABPA, 2023) foram exportadas 4,822 milhões de toneladas de carne de frango em 2022 e produzidas 14,524 milhões.

No contexto nacional, a carne de frango se destaca como um alimento amplamente presente nas mesas dos brasileiros, principalmente pelo preço acessível, facilidade de preparo, variedade de produtos disponíveis, popularidade no mercado e valor nutricional. Essas características fazem dela uma escolha excelente como fonte de proteína na alimentação (EMBRAPA, 2020).

A crescente preferência do consumidor por carnes de frango de maior qualidade tem impulsionado a demanda por inovações tecnológicas que ocorrem na forma de avaliação e produção desses alimentos (Maciel et al., 2011). Há busca por novos produtos, diversificação da oferta e valorização das matérias-primas ao explorar novos segmentos de mercado. O aprimoramento das práticas de manejo e a adoção de tecnologias modernas também contribuem significativamente para aumentos consideráveis na eficiência da produção. (Buarque, 2008).

Apesar do sucesso na produção de frangos no Brasil, ainda existem muitos problemas enfrentados na avicultura, como o desenvolvimento inadequado durante a criação, que podem apresentar prejuízos à massa óssea graças ao desequilíbrio entre formação e reabsorção (Wyart et al., 2020). A caquexia, por exemplo, é um dos desses problemas, frequentemente relatado na avicultura comercial, compromete os órgãos de interesse comercial e músculos, causando distúrbios no crescimento do animal. E é uma das principais causadoras de condenção de aves e carcaças no abatedouro (Palmeira-Borges et al., 2014). Outro entrave comumente registrado é a desuniformidade nos lotes, que podem ser causadas por doenças ou falhas no manejo, e podem aumentar a incidência de condenações por contaminação devido à dificuldade na regulagem dos equipamentos que promovem a evisceração. Com isso, há o rompimento das vísceras e extravasamento do conteúdo, favorecendo a contaminação das carcaças por excrementos, bile e outros produtos contaminados ou considerados não comestíveis (Maschio & Raszl, 2012; Paula & Groff, 2021).

2. REVISÃO DE LITERATURA

2.1 Abate de frangos de corte e sua regulamentação

A avicultura brasileira, especialmente a produção do sul e sudeste é destaque mundial pela alta produtividade de carne (ABPA, 2023). Exigindo, portanto, profissionais capacitados para a atividade, além de programas de biosseguridade, volume de produção (Olivo, 2006) e tecnologias para uma cadeia produtiva mais sustentável.

Desta forma, é imprescindível que se tenha fiscalização adequada. O Serviço de Inspeção Federal – SIF, trabalha neste seguimento, seguindo as normas do Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal – RISSPOA que conceitua carcaças como massas musculares e os ossos do animal abatido, tecnicamente preparado, desprovido de cabeça, órgãos e vísceras torácicas e abdominais, respeitadas as particularidades de cada espécie, observando ainda: nas aves, a carcaça deve ser desprovida de penas, sendo facultativa a retirada de rins, pés, pescoço, cabeça e órgãos reprodutores em aves que não atingiram a maturidade sexual. Podendo haver reinspeção, caso não esteja de acordo com as norma (Brasil, 2020). A retirada de penas é a seco, após a escaldagem (em água aquecida e renovada quando necessário) ou, por algum outro processo autorizado pelo o Departamento de Inspeção de Produtos de Origem Animal - DIPOA (Brasil, 2020).

Sobre frangos que não tiveram desenvolvimento adequado, seguindo o lote, como os caquéticos, por exemplo, RIISPOA (2020) estabelece que estes devem ser condenados, além de animais com outras doenças, como anemia ou icterícia de processos purulentos. Até lesões moderadas, nos casos de caquexia, ou outro problema de supuração, devem sofrer condenação total.

No decreto n° 9.013, de 2017 RIISPOA, os tópico I e II, que tratam de lesões nas carcaças ou órgãos, ocorre condenações nos casos de lesões discretas, pequenas que não atingem grandes áreas da carcaça, ou estão localizadas em um órgão específico, somente esta região deve ser condenada e o restante poderá ser reaproveitado. E, quando ocorre o contrário, casos de diversas lesões espalhadas pela carcaça ou órgãos. Há perda total da carcaça e esta deve ser condenada e descartada da forma correta (Brasil, 2020).

As lesões, muitas vezes podem ser causadas por enfermidades. É comum o acometimento por processos inflamatórios, artrites, aerossaculite, celulite, síndrome ascítica, entre outros. Nestes casos, deve ser realizada a avaliação pelo médico veterinário para definir o destino de tais carcaças (Brasil, 2020).

2.2 Tipificação de carcaças

A variabilidade decorrente dos fenótipos que existem nas aves, é resultante de efeitos genéticos, ambiente e também de interações entre o meio ambiente e o genótipo, e é expresso nas características da carcaça produzida.

Com isso, linhagem, raça, cruzamento, sexo, a castração, a nutrição, a fase na curva de crescimento (peso e idade) em que se dá o abate, manejo pré-abate podem influenciar na composição da carcaça ou na qualidade da carne ou em ambas (Alexandrino et al., 2020).

As características da carcaça e carne possuem uma relação direta com práticas utilizadas durante o pré-abate, iniciando no local de criação, mecanismo de transporte, e na cadeia frigorífica. Portanto, é necessário controle e atenção para garantir que se cumpra os requisitos para atender a legislação garantindo a qualidade da carne, segurança, e características sensoriais, visando a produção sustentável e proporcionando bem estar das pessoas e também das aves. Salvaguardando os desejos do consumidor em adquirir alimentos seguros e de qualidade e também a lucratividade para o produtor rural (Oliveira et al., 2006; Quadros et al., 2019).

Desuniformidade de lotes e caquexia, são exemplos comuns de problemas em frangos. Sendo que, frangos desuniformes não crescem como deveriam ou partes como asas, pernas tem tamanhos incompativeis com a ave, e frangos caquéticos apresentam características de subnutrição e magreza percebidas no escore corporal e histórico de enfermidades infecciosas ou neoplásicas, sendo que, o último, segundo a legislação, deve ser condenados no abatedouro (Brasil, 2020).

A caquexia é considerada uma das principais causas de condenações *post mortem* ocasionando prejuízos econômicos (Ferreira, 2012). Numa pesquisa realizada no Rio Grande Sul, entre os anos 2006 – 2007 e 2010 -2016, num frigorífico com inspeção federal, aves caquéticas foram as segundas maiores causas de condenações, um total de 8,48 milhões, representando 16,31% do total de condenações. Perdendo para carcaças com aspecto repugnante (Procópio, 2020).

Segundo Oliveira *et al.* (2014), a doença é decorrente do manejo deficiente das aves, das más condições iniciais de criação e da qualidade do pintinho, temperatura ambiental, saúde, consumo de água e ração, densidade de estocagem e síndrome do nanismo durante a primeira semana de idade. A condição é caracterizada por malformação muscular e redução da massa, cor da carne escurecida, protrusão da quilha do esterno e ausência e perda de quase toda a gordura (Nery et al., 2017).

2.3 Avaliação morfológica de frangos de corte

Desde sua orgem, os indivíduos passam por um processo contínuo de crescimento e desenvolvimento. O crescimento animal é marcado pelo aumento de peso, comprimento, altura e circunferência em função da idade. Enquanto o desenvolvimento implica em transformações na estrutura corporal e nas funções do organismo (Rodrigues Filho et al*.,* 2011).

A análise de tamanho e peso relativo dos órgãos tem importância significativa especialmente por influenciar diretamente sobre rendimento de carcaça e exigência de energia. O peso das partes não integrantes da estrutura corporal varia em cada especíe animais e dependem da raça/linhagem, idade e de fatores nutricionais (Veloso et al., 2002).

Em relação a frangos de corte, a seleção genética nos últimos 60 anos concentrou- intensamente nas características de produção, em especial, taxa de crescimento e eficiência alimentar. Com isso, houve aumento de massa muscular peitoral associada à maior adiposidade abdominal, doenças ósseas e cardiovasculares (Hartcher & Lum, 2020). Desta forma, faz-se necessário o estudo da conformação da carcaça e suas correlações com características dos órgãos internos em linhagens modernas saudáveis Kokoszyński (2017) e em condições de desuniformidade.

3. HIPÓTESE

Os frangos de corte desuniformes podem ser aproveitados, na indústria, podendo reduzir perdas econômicas nos abatedouros.

4. OBJETIVO

Analisar os aspectos estruturais de diferentes padrões de frangos de corte por

meio da avaliação da densidade mineral, conteúdo mineral, massa magra e gordura corporal, morfologia musculoesquelética e de órgãos de diferentes sistemas, e verificar se aves desuniformes poderiam ser aproveitadas, ainda que em produtos processados, e reduzir perdas ecônomicas no abatedouro.

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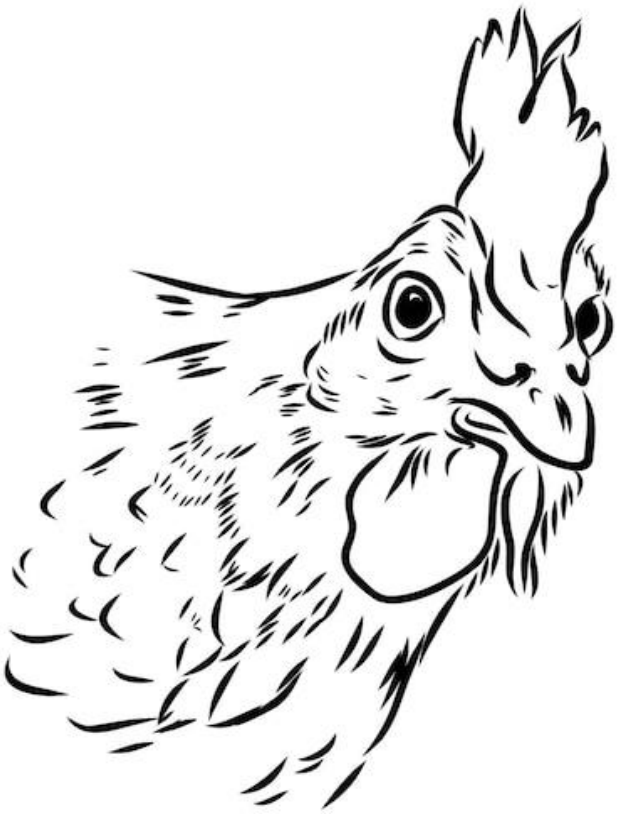
CAPÍTULO 2



CAPÍTULO 2 – Musculoskeletal and visceral quality of broilers with different pore patterns

Musculoskeletal and Visceral Quality of Broilers with Different Body Patterns

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ABSTRACT

The body pattern of broilers can be influenced by diet, environment, stress, health and management. Considering the importance of body structure of broilers in slaughterhouse condemnations, this research was carried out with the objective of analyzing body composition, bone mineral density and musculoskeletal and visceral morphology of broilers with different body attributes from commercial slaughterhouses. Forty-eight plucked broilers from two different strains were distributed into three groups: standard, uneven and cachectic. The broilers were evaluated for lean mass, body fat, bone mineral density, bone mineral content, macroscopic, musculoskeletal and visceral analysis. It was found that bone mineral density was lower in the uneven and cachectic group compared to the standard (P≤0.05), with cachectic broilers having lower bone mineral content compared to other groups. There was no difference in the relative weight of body fat, however, a significant difference (P≤0.05) was observed among the three groups in the analysis using the X-ray absorptiometry device. In the macroscopic evaluation, the body weight of broilers in standard group was greater compared to other groups, while the relative weight of proventriculus, gizzard, liver, duodenum, jejunum, cardiovascular structures and kidney was greater in cachectic compared to others. The relative weights of pectoral and gastrocnemius muscles and the diameters of gastrocnemius, sartorius, proventriculus, gizzard and pancreas and length of jejunum were greater in the standard group. Cachexia, as a systemic syndrome, causes a reduction in musculoskeletal quality and interferes with the proportionality of organs, resulting in significant economic loss in the slaughterhouse.

Key-words: adiposity, body composition, bone density, poultry science, morphology

1. INTRODUCTION

With the increase in productivity, consumer demands regarding the guarantee of animal health and food quality grow. Despite Brazil occupying a prominent position in global poultry farming, failures related to carcass quality and a large number of condemnations result in significant economic losses for the segment (Oliveira *et al*., 2021).

Factors such as nutritional and sanitary management and inadequate environmental conditions are the main causes of broilers carcass condemnation, so, the three most frequent causes are cachexia (42%), generalized congestion (29%) and non-purulent skin lesions (14%) (Salines *et al*., 2017). As a result, poultry

companies intend to improve technologies to standardize batches and meat quality, providing maximum genetic expression of broilers (Silva Costa *et al*., 2012).

Dentre os principais tipos de carcaças que sofrem condenação, destacam-se as provenientes de frangos de corte caquéticos (Ferreira *et al*. 2012) que são caracterizadas pela diminuição do tamanho e força dos músculos, protuberância do esterno e escassez de gordura corporal e aspecto arroxeado do tecido muscular na carcaça. O maior número de condenações registradas, neste ano, foi de 107.988, no mês de junho, no estado do Paraná (Brasil, 2023).

Among the main types of carcasses that are condemned, those from cachectic broilers (Ferreira *et al*., 2012) which are characterized by decreased muscle size and strength, protuberance of the sternum and lack of body fat and a purplish appearance of the muscle tissue in the carcass. The highest number of convictions recorded this year was 107,988, in the month of June, in the state of Paraná (Brazil, 2023).

Diversas condições podem desencadear a caquexia, porém as causas mais comuns estão relacionadas à nutrição e à presença de infecções. Apesar de carcaças caquéticas apresentarem cor escurecida, Qiao *et al*. (2001) citaram que o manejo pré-abate e a predisposição genética são os principais fatores que influenciam nesse aspecto.

Several conditions can trigger cachexia, but the most common causes are related to nutrition and the presence of infections. Although cachectic carcasses have a darkened color, Qiao *et al.* (2001) mentioned that pre-slaughter management and genetic predisposition are the main factors that influence this aspect.

Batch uneven can cause rejections at the slaughterhouse. It is a challenge faced in poultry farming and industry and happens especially when the housing density is

greater than 30 kg/m² (6.2 lb/ft²) in open houses with fans and 42 kg/m² (8.6 lb/ft²) in closed houses with tunnel ventilation (Cobb-Vantress, 2018). This situation results in competition among broilers for space in bed, feeders and drinkers, favoring dominant chickens that have more access to these resources, resulting in greater weight gain compared to other broilers. This scenario results in uneven avian growth, which negatively influences final performance and carcass yield (Luchesi, 1998).

According to Araújo *et al.* (2012), bone growth don`t keep up with rapid muscle growth in modern chicken strains, resulting in a higher incidence of leg problems and bone fragility. Furthermore, artificial selection has resulted in developmental trade-offs with the reallocation of resources to maximize nutrient absorption and pectoral muscle mass coinciding with relative decreases in the size of others such as the heart and brain (Schmidt *et al*., 2009).

Além das características musculoesqueléticas e da adiposidade, a carcaça de frangos pode apresentar variações na estrutura do trato digestório, que, segundo Szczepańczyk (1999), estão relacionadas principalmente ao peso, comprimento e largura dos diferentes segmentos.

In addition to musculoskeletal characteristics and adiposity, chicken carcasses may present variations in the structure of the digestive tract, which, according to Szczepańczyk (1999), a re mainly related to the weight, length and width of the different segments.

Destacando-se a literatura citada acima, o presente trabalho foi proposto com o objetivo de analisar os aspectos estruturais de diferentes padrões de frangos de corte por meio da avaliação da densidade mineral, conteúdo mineral, massa magra e gordura corporal, morfologia musculoesquelética e de órgãos de diferentes sistemas,

e verificar se aves desuniformes poderiam ser utilizadas, ainda que em produtos processados, e reduzir perdas ecônomicas no abatedouro.

Highlighting the literature cited above, the present work was proposed with the objective of analyzing the structural aspects of different patterns of broiler chickens through the evaluation of mineral density, mineral content, lean mass and body fat, musculoskeletal and morphology of different organic systems, and verify whether uneven broilers could be used, even in processed products, and reduce economic losses in the slaughterhouse.

2. MATERIAL AND METHODS

2.1. Ethical approval

This study was approved by the Ethics Committee on the Use of Animals (Universidade Estadual Paulista “Julio de Mesquita Filho” – UNESP / Campus de Jaboticabal), Protocol No. 3689/21.

2.2. Experimental characterization and classification and selection of broilers

Broiler chickens, slaughtered at 42 days of age, males and females, from the Cobb 500 and Ross lines were from a commercial slaughterhouse (state of São Paulo, Brazil). The classification and selection of broiler chickens according to sex was carried out in the hatchery. While the selection of groups was made at the slaughterhouse, according to weight and muscle coverage, immediately after plucking. The distribution was carried out in a randomized block design with three groups and 16 broilers were used in each group: standard (n=16) (adequate body weight and muscle coverage),

uneven (n=16) (lower average body weight to the standard group and less muscle coverage) and cachectic (n=16) (reduced size and weight, muscle atrophy characterized mainly by insufficient coverage of the pectoral muscle and prominence of the sternum) (Figure 1),according to the classification established by RIISPOA (Brazil, 2020). Then, the plucked broilers were placed in refrigerated boxes and transported to the Bone Densitometry and Body Analysis Laboratory of the Department of Morphology and Animal Physiology of the Faculty of Agricultural and Veterinary Sciences of Jaboticabal for analysis of body composition and total bone mineral density.

2.3. Weight analysis, measurements, body composition and bone mineral density

The plucked broilers were weighed individually and measured with a common millimeter measuring tape for length. The equipament was calibrated with was positioned in supine position to avoid bone overproposition. And total body scanning was performed using the Hologic® Discovery Si, GE dual-energy X-ray absorptiometry (DXA) device. The values of bone mineral density (BMD) (g), bone mineral content (BMC) (g), lean mass (%) and body fat (g) were estimated.

2.4. Macroscopic analysis

After analysis by DXA, each broiler was evaluated regarding its general appearance, photodocumented and dissected for visceral, muscular and bone analysis. To analyze the viscera, immediately after opening the coelomic cavity, the air sacs were inspected and classified according to color, presence of exudate and fibrin.

The heart, lungs, proventriculus, liver, muscular ventricle, intestines, pancreas and kidneys were inspected and classified according to color, weight, consistency (normal, firm or friable), shape, size and presence of lesions. The relative weight of the bodies of interest was also calculated. Furthermore, the fat present in the coelomic cavity, in the abdominal region and adipose tissue around the proventriculus, empty gizzard and intestines, was dissected and weighed. The liver was evaluated for normal (brown) or altered (yellowish or greenish) color, presence of spots, focal or multifocal lesions. The cecal tonsils were incised and dissected at the ileocecal junction. The muscles were individualized and weighed and the pectoral, gastrocnemius and sartorius muscles were dissected, weighed and measured. Then, the femur and tibiotarsus were removed, weighed and evaluated regarding the length and perimeters of the proximal epiphysis, diaphysis and distal epiphysis (respecting the contours) of the respective bones of the right pelvic limbs of broilers from the different groups.

2.5. Statistical analysis

Data consistency and analysis of variance (ANOVA) were performed with the R software and the averages of the results obtained were compared using the LSD test. Statistically significant differences were found where p was less than 5% ($p<0.05$). The values obtained during the experiment were expressed as arithmetic averages with their respective standard deviations.

3. Results and discussion

In Table 1, the standard group presented the highest BMD values (0.13g), differing from the uneven and cachectic groups ($P\leq0.05$), which presented equal

values (0.12g) (P≥0.05). For BMC, a difference was observed among the three groups (P≤0.05), with the highest value for the standard group (40.16g) and the lowest for the cachectic group (22.80g). It was observed, therefore, that the skeleton of plucked broilers from the standard group was denser and probably with greater bone area and thickness, reflecting in greater BMC in relation to the other groups. Bone is a dynamic tissue that undergoes physiological processes of formation and resorption with phases finely regulated by local or systemic factors that mediate the connections among osteoblasts, osteocytes and osteosclates to maintain homeostasis (Kim & Koh, 2019). Therefore, it is suggested that these processes may be unbalanced in uneven and cachectic broilers, resulting in loss of density and bone mineral content, and, consequently, lower bone quality.

Regarding lean mass and body fat, there was a significant difference among groups (P≤0.05). The standard group had the highest amount of lean mass and body fat in relation to the other groups, with the uneven and cachectic groups also differing (P≤0.05). Lee *et al*. (2007) observed that mice that suffered depletion of the gene that expresses osteocalcin in osteoblasts present decreased β-cell proliferation, glucose intolerance and insulin resistance. In this way, they concluded that the skeleton plays a neuroendocrine role, controlling the body's energy metabolism. Thus, the results of the present study suggest that the loss of lean mass and body fat in uneven and cachectic broilers could be related to lower bone quality in these groups of broilers, probably due to the smaller population of osteoblasts and reduced amount of osteocalcin, which acts as a hormone, controlling energy metabolism in mammals (Lee *et al.*, 2007).

Furthermore, according to Argiles *et al*. (2015), several tissues are involved

in cachexia, characterized by loss of body weight, muscle and adipose atrophy and inflammation, and is often associated with anorexia. It is noteworthy that muscle tissue appears to be one of the main ones involved in atrophy during cachexia, with sarcopenia being the degenerative loss of skeletal muscle mass, quality and strength, which characterizes the lower lean mass observed in the cachectic group (Table 1). The molecular mechanisms associated with cachexia and sarcopenia share some common trends. The loss of muscle mass is the result of a combination of imbalance between synthetic and degradative protein pathways, together with increased myocyte apoptosis and decreased regenerative capacity. Oxidative pathways are also altered in skeletal muscle during loss of muscle mass and this appears to be a consequence of mitochondrial abnormalities that include altered morphology and function with decreased ATP synthesis.

In the qualitative macroscopic analysis of the organs evaluated, it was observed that the standard and uneven groups did not present visible changes in the liver and kidneys. In the uneven group, an increase in the cecal tonsils was observed in some broilers, with hemorrhagic changes evident after dissection (Figure 2A). In the cachectic group, kidney and liver changes were found in some birds. Figure 2B shows the kidneys of birds from the standard group. Figure 2C shows that there was a change in color in the kidneys, probably due to the presence of urate crystals, according to Mallmnn & Dilkin (2020).

In figure 2D, the liver can be seen with normal color and margins. In contrast, in images 2E and 2F, heterogeneous coloration of the liver is observed, with diffuse regions and increased contour of the organ, lesions suggestive of hepatitis. Palmeira-Borges *et al*. (2006) analyzed 400 broiler carcasses and observed macroscopic

changes in 35%. These changes may be due to bacterial and parasitic infections or toxicosis and cardiovascular disorders (Horrer, 1996). And Barcelos *et al.* (2006), macro and microscopically analyzed 100 samples of livers from two different slaughterhouses and found macroscopic changes in 90 of the total samples, 21 with a diagnosis of heterophilic cholangium hepatitis and 9 with heterophilic pericolangitis. These lesions are suggestive of infection by *Clostidium perfringens* (Randal & Reece, 1996), which can compromise the bird's development.

Table 2 contains data from the macroscopic analysis of birds from the standard, among and cachectic groups. The cachectic group stood out with higher relative weight values compared to the other groups (P≤0.05) for some of the parameters evaluated. There was a significant difference (P≤0.05) among the three groups regarding the average weight of the birds and also body fat. In the research by Pereira *et al*. (2019) there was no difference in the weight of abdominal fat among the lines evaluated (Cobb 500 and Ross) but, in terms of sex, females had a higher percentage of body fat.

Kokoszyński *et al*. (2017), studied the morphological characteristics of different commercial strains and observed no effect of the genotype on the liver, heart, gizzard and spleen, while, comparatively, the proventriculus was heavier in one of the strains analyzed. In the present study, a difference (P≤0.05) was observed in the relative weight of these organs (Tables 2 and 3), demonstrating that the size of the bird directly interferes in the viscera yield, due to the proportionality and body size in standard, among birds and cachectic.

In the present study, the relative weight of the liver was greater in the cachectic group compared to the standard group (P≥0.05), and the among liver did not differ between the two groups (P≤0.05). According to Palmeira-Borges *et al*. (2006),

the liver is one of the organs most commonly affected in cachexia, and these authors observed 36% of birds with liver changes in a batch of 400 broiler chickens.

Work related to the morphological aspects of the digestive system, such as by Sousa *et al.* (2015), Ito & Miyaji (2020), Liboni *et al*. (2013), can contribute significantly to the health and performance of birds, as they are essential inputs for understanding the mechanisms responsible for the functioning of the digestive tract, especially in broiler chickens.

In the present research, the weight of some segments of the small intestine behaved differently (Table 2). The relative weight of the duodenum was greater in the cachectic group (P≥0.05), but did not differ between the standard and non-uniform (P≥0.05) while the weight of the jejunum and ileum differed uneven among the three groups (P≥0.05). Bird health is linked to food, therefore, adequate supply of a balanced diet is essential. This statement can be proven in the study by Franzo *et al.* (2006) who showed low weight of organs in the digestive system of broiler chickens and layers subjected to dietary restriction.

Regarding the length of the intestinal segments (Table 2), it was observed that there was no statistical difference among the groups for the duodenum and ileum. In the jejunum, the standard group presented a higher average length compared to the other groups (134.56 cm), which did not differ from each other (P≥0.05). When analyzing the morphology of the small intestine of Cobb 500 chickens, slaughtered at 46 days of age, Sousa *et al*. (2015) observed a shorter length of the jejunum (110.88 cm) when compared to the present study, and higher average values for the duodenum and ileum, 32.38 and 20.25 cm, respectively. The three groups presented average values for the length of the ileum similar to those observed in the literature,

corroborating Ito & Miyaji (2020) who highlighted the length of 13 to 18 cm for this segment.

There was no difference in the weight of the pancreas (P≥0.05), only in the length of the standard group, which was greater (P≤0.05) in relation to the uneven and cachectic group, which did not differ from each other (Table 2). According to López & Baião (2004) and Engberget *et al.* (2002) the type of diet can influence the size of the pancreas. The authors observed that birds fed with coarse-grained rations had heavier pancreases compared to birds fed with medium-grained rations.

Regarding the proventriculus (Table 2), there was a significant difference (P≤0.05) between the weight values of the cachectic group in relation to the others. Diameter and length measurements were greater in the standard group, with no difference between the other two groups (P≥0.05). In the research by Nunes *et al.* (2011), replacing corn with sweet potato flour influenced proventriculus weight, with a decreasing quadratic and linear effect. Gonzáles-Alvarado *et al.* (2008) observed greater proventriculus weight in broiler chickens fed soybean hulls and rice instead of corn. According to the authors, the solubility capacity of soybean hulls in water promotes a reduction in the passage of food content from the proventriculus to the gizzard. The results observed in Table 3 show that the cachectic group presented higher relative weight values of the cardiorespiratory system organs and kidneys when compared to the other groups. The standard and uneven groups differed only in heart weight. The microscopic findings carried out by Nery *et al*. (2017) showed no presence or signs of infectious agents or microscopic lesions in the heart and kidneys of cachectic broilers, showing that not all cases of cachexia are due to infectious diseases.

Com relação ao peso do baço (Tabela 3), observou-se que os valores obtidos para os três grupos corroboraram com a literatura, pois, de acordo com Nickel (1977), o baço de aves pode apresentar de 1.5g a 4.5g. Os pesos médios encontrados na presente pesquisa foram de 1.92g a 3.07g.

Regarding the weight of the spleen (Table 3), it was observed that the values obtained for the three groups corroborated the literature, since, according to Nickel (1977), the spleen of birds can weigh from 1.5g to 4.5g. The average weights found in the present research were from 1.92g to 3.07g.

As for the lung, there was a significant difference between the cachectic and uneven groups (P≤0.05) and the standard group did not differ from the two. The cachectic group presented the highest values and the uneven group, the lowest (Table 3). The lungs are organs susceptible to various avian diseases, in this sense, Taunde *et al.* (2021), found uneven in batches of broiler chickens affected by colibacillosis, in addition to fibrin deposition in the heart, compromising its development and cardiac activity.

Regarding the kidneys, there was a statistical difference between the weight of the cachectic group in relation to the others (P≤0.05). But the standard group did not differ statistically from the uneven group (Table 3). Palmeira – Borges *et al.* (2006) evaluated lesions in 400 carcasses of cachectic chickens and found kidney lesions in 32 animals (8%) such as caseous exudate, yellowish color and atrophy of the organ. It is suggested that cachexia may affect the functioning of vital organs such as the kidney.

In Table 4, the femur weight of the standard group showed a significant difference (P≤0.05) in relation to the cachectic group, and the uneven group did not

differ from both (P≥0.05). Barreiro *et al*. (2011) carried out research on morphological parameters of chicken femurs at different growth stages and obtained an average of 14.96g, a result similar to that of the standard group in this research, 14.98g.

The length of the femur was greater in the standard group compared to the others (P≤0.05). It is suggested that the significant loss of lean mass may have affected the deposition of bone mass in the uneven and cachectic groups, since, according to Buckner *et al.* (1950), the length of the femur correlates with the weight of the bird, therefore, chickens in the standard group had greater length compared to the other groups.

The diameters of the proximal epiphysis, diaphysis and distal epiphysis of the femur had a similar behavior to the length, with the standard group standing out with higher average values (P≤0.05) in relation to the others, which did not differ from each other (P ≥0.05). In research by Bruno (2002), diaphysis length and femur diameter values were reduced after food restriction. Kwakkel *et al*. (1998), showed that the femur may be more sensitive to bone modeling. Furthermore, according to Applegate & Lilburn. (2002) femoral morphological changes are faster and more intense than tibial ones, and are associated with a greater number of bone disorders in fast-growing chickens.

The average weight, length and diameter of the proximal epiphysis of the tibia in the standard group were significantly different (P≤0.05) in relation to the others, which did not differ from each other (P≥0.05). There was no statistical difference (P≥0.05) in the diameter of the tibial shaft among the groups. It is suggested that the loss of compact bone predominant in the diaphysis is slower in relation to epiphyses made up predominantly of cancellous bone. In the research by Murakami *et al.* (2009)

weight and tibia length values were similar (24g and 12cm) to those found in the present research for groups of chickens considered standards (23.54g and 11.88cm). The distal epiphysis of the tibia differed among the three groups (P≤0.05), being larger in the standard group and smaller in the uneven group (Table 4).

According to Almeida Paz & Bruno (2006), adequate nutritional levels promote the normal development of bone tissue. Therefore, it is inferred that the lower values presented by the uneven and cachectic groups may be related to the difficulty in accessing the feeders, thus, the amount of feed ingested may not have supplied the broilers' needs.

In the macroscopic analysis of the muscles (Table 5), it was observed that the standard group presented the highest value of relative weight of the pectoral muscle (P≤0.05) compared to the uneven and cachectic groups. There was no statistical difference (P≥0.05) in the relative weights of the gastrocnemius and m. sartory among groups. The length and diameter of m. gastrocnemius did not differ between the standard and uneven groups, but differed from the cachectic group (P≤0.05). The length of m. sartorius was greater in the standard group (P≤0.05) and the same for uneven and cachectic groups.

Pereira *et al*. (2019), analisaram diferentes linhagem e observaram que não houve diferenças estatísticas para peso do músculo peitoral entre as linhagens Cobb 500 e Ross e entre os sexos. Segundo Oliveira *et al.* (2014), temperaturas inadequedas podem prejudicar o desempenho de frangos de corte contribuindo ou causando caquexia e desuniformidade dos lotes. Oliveira *et al*. (2006), analisando desempenho de carcaças, observaram efeito negativo de alta e baixa temperatura (32ºC e 16ºC), sobre o peso de peito de frangos de corte.

Pereira *et al*. (2019), analyzed different strains and no observed statistical differences for pectoral muscle weight between the Cobb 500 and Ross strains and between sexes. According to Oliveira *et al.* (2014), inadequate temperatures can harm the broilers performance, contributing to major frequency of cachexia and uneven in batches. Oliveira *et al*. (2006) evaluated carcass performance and observed a negative effect of high and low temperatures (32ºC and 16ºC) on the breast weight of broiler chickens.

Mazzucatto *et al.* (2009), analyzing histopathological changes in the sartorius, cardiac, pectoralis latissimus dorsi muscles and sciatic and optic nerves of broiler chickens, observed that the sartorius muscle was the most affected by injuries. Inflammatory infiltrates were found between the fibers and perimysium, fibers in degeneration phase and atrophy of muscle fibers. The connective tissue sheaths between the fibers and bundles appeared thickened. It is suggested that m. sartorius may be more sensitive to the drugs used in the experiment: monensin and roxarson than other muscles, and histopathological changes may influence the visual appearance of the muscle.

Regarding the gastrocnemius muscle, Rosa *et al.* (2018), analyzing the performance of chicken carcasses, found that the addition of creatine to the diet increased slow-twitch red fibers and fast-twitch white fibers. Other research showed that ingesting 1% pectin reduced lipid concentration in the gastrocnemius muscle (Silva, 2012).

It is also noteworthy that cachexia causes distinct changes in striated muscles, with skeletal muscle loss being progressive and faster when compared to cardiac muscle (Tables 3 and 4). However, although there is no significant reduction in cardiac

muscle mass, according to Rausch *et al*. (2021), cachexia is critical for the functionality of the organ, causing serious cardiac abnormalities such as heart failure.

4. Conclusions

The long bones of the pelvic limb present site-specific morphological variations in different conformational patterns of broiler chickens, which demands that future studies to be carried out on the proportion of compact and spongy bone tissue with the aim of understanding the bone characteristics of uneven and cachectic birds.

Lower adiposity and reduced lean and bone mass affect the body composition of uneven and cachectic broilers. Cachexia, as a systemic syndrome, causes a significant reduction in musculoskeletal quality in birds and interferes with the proportionality of organs of commercial interest, especially the heart and gastrointestinal tract.

As, through macroscopic analysis, several structures of the birds in the uneven group have similar characteristics to the standard group, demonstrating that uneven broilers could be used as feedstock for processed products, reducing economic losses at the slaughterhouse.

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Table 1. Bone mineral density analysis (BMD)*, bone mineral content (BMC), lean mass and total body fat.

Group (N=16)	BMD g/cm²	BMC (g)	Lean mass (g)	Body fat (g)
Standard	0.13 [a]	40.16 [a]	2486.99 [a]	590.14 [a]
Uneven	0.12 [b]	27.62 [b]	1568.29 [b]	369.06 [b]
Cachectic	0.12 [b]	22.80 [c]	1152.13 [c]	262.80 [c]
P-value	0.020*	2.071e-10 ***	2.2e-16 ***	1.449e-11***
CV*	10.45	19.22	16.44	24.25

Means with different letters in the columns are significant at the level of P ≤ 0.05 by the least significant difference (LSD) test
Bone Mineral Density (BMD); Bone Mineral Content (BMC).
Coefficient of Variation (CV)

Table 2. Average weight (carcass kg), relative weight (organs and abdominal fat%), diameter (proventriculus cm) and length of gastrointestinal tract organs (cm) of standard, uneven and cachectic broiler chickens slaughtered at 42 days of age.

	Weight (kg)			Weight (%)						Diameter	Length				
Group	PC	AF	Prov	Gizzard	Liver	Panc	duo	Jej	Ileum	Prov	Prov	Panc	duo	Jej	Ileum
S	2.96 [a]	0.21 [a]	0.35 [b]	0.11 [b]	0.19 [b]	0.17	0.42 [b]	0.16	0.24	6.91 [a]	5.30a	13.19 [a]	29.50	134.56 [a]	19.31
U	2.09 [b]	0.17 [b]	0.37 [b]	0.14 [a]	0.23 [a b]	0.19	0.52 [b]	0.19	0.23	6.00b	4.62 [b]	10.75 [b]	29.25	115.80 [b]	16.07
C	1.50 [c]	0.16 [a]	0.53 [a]	0.15 [a]	0.26 [a]	0.20	0.70 [a]	0.20	0.29	5.66b	4.73 [b]	10.87 [b]	27.41	108.06 [b]	17.51
P-value	2.2e-16 ***	0.28	0.001***	0.001***	0.07	0.42	0.002**	0.19	0.19	0.003**	0.02*	0.001***	0.51	9.821e-05 ***	0.17
CV*	13.43	42.12	22.06	14.20	16.27	21.08	20.43	23.83	35.99	31.60	14.20	29.19	13.45	41.38	26.56

Standard (S); Uneven (D); Cachectic (C); Carcass Weight (PC); Abdominal Fat (AF); Proventriculus (Prov); Pancreas (Panc); Duodenum (Duod); Jejunum (Jej).
Means with different letters in the columns are significant at the level of $P \leq 0.05$ by the least significant difference (LSD) test.
Coefficient of Variation (CV)

Table 3. Relative weight (%) of cardiorespiratory system organs and kidneys of broiler chickens from the standard, uneven and cachectic groups slaughtered at 42 days of age.

Group (N=16)	Heart (%)	Spleen (%)	Lungs (%)	Kidneys (%)
Standard	0.45 [c]	0.10 [b]	0.59 [a b]	0.60 [b]
Uneven	0.52 [b]	0.9 [b]	0.56 [b]	0.59 [b]
Cachectic	0.64 [a]	0.13 [a]	0.65 [a]	0.84 [a]
P-value	6.018e-05 ***	0.002 **	0.072	2.664e-06 ***
CV*	23.30	30.75	18.48	20.28

Means with different letters in the columns are significant at the level of P ≤ 0.05 by the least significant difference (LSD) test. Coefficient of Variation (CV).

Table 4: Average weight (kg), diameter (cm) and length (cm) of the femur and tibia of broiler chickens of the standard, uneven and cachectic groups slaughtered at 42 days of age.

	Tíbia					Fêmur				
GROUP (N=16)	Femur Weight	Femur Length	Femoral Proximal Epiphysis Diameter	Diaphysis of the Femur	Distal Femoral Epiphysis Diameter	Tibia Weight	Tibia Length	Tibial Proximal Epiphysis Diameter	Tibial Diaphysis Diameter	Diameter of the distal epiphysis of the tibia
Standard	14.98 [a]	8.13 [a]	7.39 [a]	3.58 [a]	8.11 [a]	23.54 [a]	11.88 [a]	8.93 [a]	3.23	8.14 [a]
Uneven	13.34 [a b]	7.50 [b]	6.52 [b]	3.24 [b]	7.02 [b]	18.53 [b]	10.19 [b]	7.58 [b]	2.92	6.82 [c]
Cachectic	12.07 [b]	7.03 [c]	6.44 [b]	3.31 [b]	6.81 [b]	17.69 [b]	9.90 [b]	7.72 [b]	2.99	7.28 [b]
P-value	0.011 *	2.895e-06 ***	0.002**	0.017*	4.107e-05 ***	0.001 ***	6.003e-06 ***	7.13e-05 ***	0.191	8.099e-07 ***
CV*	18.72	18.72	6.68	9.30	11.03	9.92	20.41	9.34	14.71	7.22

Means with different letters in the columns are significant at the level of P ≤ 0.05 by the least significant difference (LSD) test.
Coefficient of Variation (CV)

Table 5. Relative weight, length and diameter of the superficial pectoralis muscle (m.), m. gastrocnemius and m. sartorius.

	Muscle weight (%)			Length (cm)		Diameter (cm)	
GROUP (N=16)	Breastplate	Gastrocnemius	Sartorius	Gastrocnemius	Sartorius	Gastrocnemius	Sartorius
Standard	0.32 [a]	0.47	0.41	8.06 [a]	9.55 [a]	7.44 [a]	6.59 [a]
Uneven	0.28 [b]	0.41	0.39	7.31 [a]	8.19 [b]	7.00 [a]	5.97 [a]
Cachectic	0.25 [c]	0.39	0.38	6.30 [b]	7.69 [b]	5.45 [b]	4.96 [b]
P-value	2.776e-05 ***	0.099	0.864	0.002 **	0.004 **	4.39e-06 ***	0.003 **
CV*	44.69	26.01	47.38	47.38	18.25	15.57	22.16

Means with different letters in the columns are significant at the level of P ≤ 0.05 by the least significant difference (LSD) test.
CV: Coefficient of Variation

MUSCULOSKELETAL AND VISCERAL QUALITY OF BROILER CHICKENS OF DIFFERENT BODY PATTERNS

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IMAGES

Figure 1. Adult plucked broilers. A: standard chicken (1); B: uneven chicken (2); C: cachectic chicken. Source: Morpholab, 2022. (Page 14).

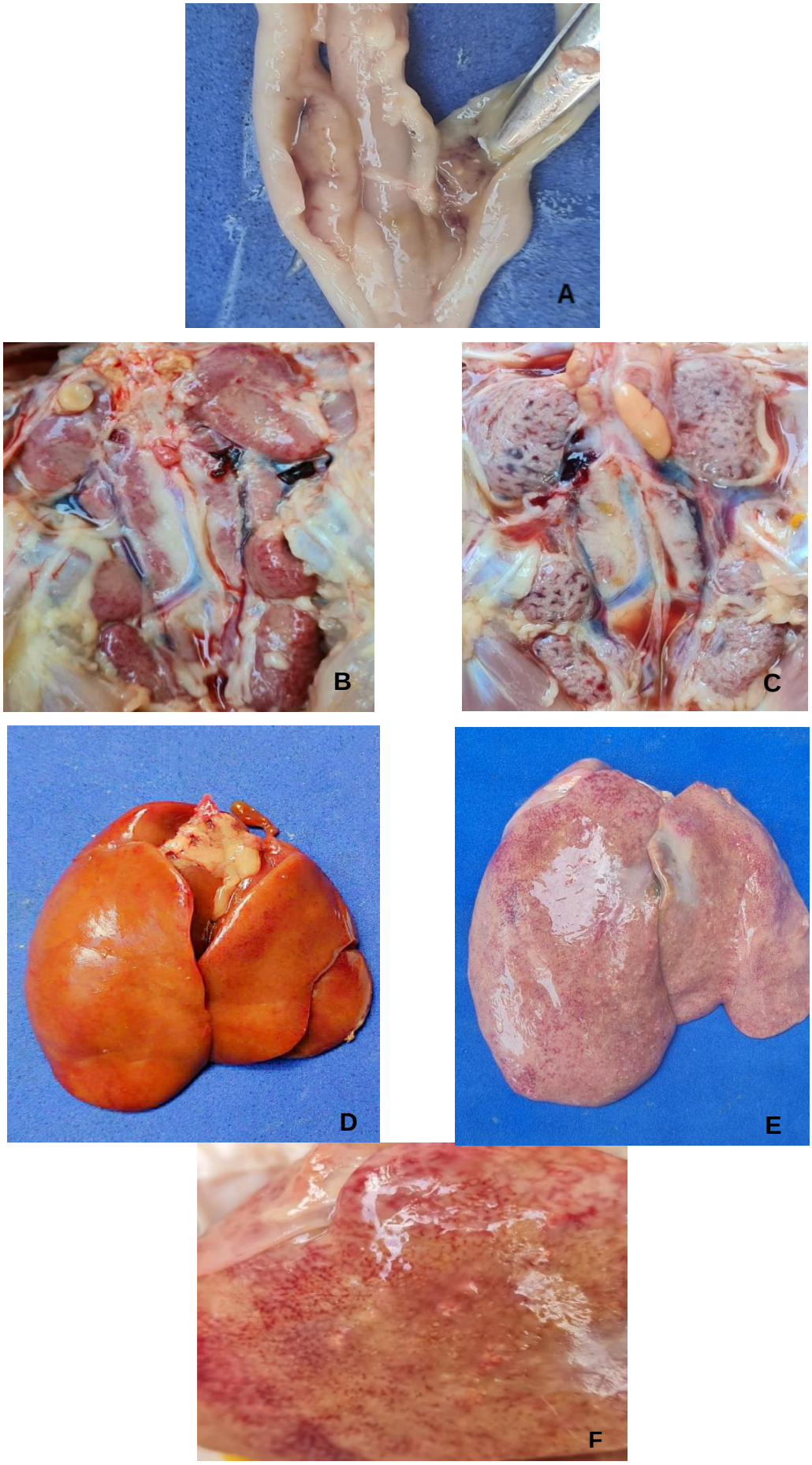

Figure 2. Photographic images of cecal tonsils, kidneys and liver of broiler chickens. A: Hemorrhagic cecal tonsils of uneven chicken; B: kidney from the standard group; C: kidney from cachectic chicken; D: standard broiler liver; E: cachectic broiler liver F: hepatic parenchyma with whitish nodules from cachectic broiler. Source: Morpholab, 2022. (Page 17).