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Effect of Diets Containing Dried Cashew Apple Pulp (*Anarcadium occidentale*) on Local Pigs Health Status *via* Biochemical and Hematological Parameters in South's Senegal

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Abstract: Despite its recognized zootechnical advantages in improving food security and reducing poverty worldwide, the pig remains neglected, and unlike other animal species, its breeding is little studied in Senegal. Mainly raised extensively in rural areas of Casamance, pig farming still faces a major feeding problem, hence the need to make the most of inexpensive, locally available feed resources that are often overlooked by stakeholders, while ensuring their harmlessness for the health of the animals. In this context, the aim of this study was to evaluate the effect of incorporating dried cashew apple pulp (CAP) into the diets on the health status of local pigs, *via* biochemical and hematological parameters. Conducted during 112 days in the Sédhiou region, the trial involved 84 local piglets weighing 11 kg body live weight and aged 3 to 5 months. These piglets were evenly distributed according to live weight and sex into 4 batches of 21 subjects each, subdivided into 3 replicates of 7 subjects, corresponding to the 4 dietary treatments for fattening pigs, CAP_0 (control feed), CAP_{10}, CAP_{15} and CAP_{20} containing 0, 10, 15 and 20% CAP respectively. The pigs were reared in a station, identified, dewormed and fed *ad libitum* with the mealy diets (CAP_0, CAP_{10}, CAP_{15} and CAP_{20}) produced, and watered with drinking water. On the eve of start-up (day-1), on days 60 and 112 of the trial, two blood samples (in dry and EDTA tubes respectively) were taken from each of the pigs batched according to the dietary feed, and subjected to biochemical and hematological analysis respectively. The biochemical and hematological data obtained or calculated in the Excel by treatment were subjected to a one-factor ANOVA test at the 5% threshold with SPSS-v.23 software, supplemented by the DUNCAN post-hoc test to locate variations between means, when the former showed a significant difference between treatments. The Student's t-test of the same software was also used to compare the averages of biochemical and hematological parameters obtained in all pigs of the different batches before the start of the trial with those obtained in subjects fed each of the CAP-based diets during the experiment. The results show that the incorporation of CAP into the diet of growing-finishing pigs had no adverse effect on biochemical and hematological parameters. It was concluded that CAP can be incorporated up to 20% in the diet of fattening pigs without affecting their health status.

Keywords: Biochemical and Hematological Parameters, Diets, Dried Cashew Apple Pulp, Local Pig

1. Introduction

Because of its zootechnical advantages (short reproduction and production cycle, high prolificacy, great adaptability and ability to make the most of diverse diets), the pig is one of the species that should be promoted to improve food security and poverty worldwide [1]. It remains neglected and its breeding is little studied in Senegal, unlike other animal species. It is raised mainly in rural areas of Casamance in an extensive way, with a diet based essentially on household waste and residues available in nature. The previous work has reported that pig farming in Casamance faces a major feeding problem [2]. While sustainable development of this livestock farming sector must be based on improved breeding practices, in particular, a feed well adapted to the socio-economic conditions of the farmers. The development of cheap, locally-available feed resources, often little-known by stakeholders, could be an alternative, while taking into account the influence of the use of these resources on the health of the animals. This is the case for dry cashew apple pulp (CAP), a cashew nut by-product and residue obtained after extraction of cashew apple juice, which is highly under-exploited in Casamance, despite the fact that this region accounts for more than 80% of cashew nut cultivation areas in Senegal, and for an annual production of cashew apple dry matter estimated at 243,320 tonnes in 2020 [3-5]. What's more, some authors have reported that despite the existence of certain anti-nutritional substances, this CAP can be incorporated into pig diets at relatively low rates (less than 20%), without any negative effect on their health and zootechnical performance [2, 6-8]. Admittedly, there is very little previous work on the use of CAP in pig feed in Senegal, but to our knowledge, no study evaluating the influence of CAP-based diets on pig health *via* biochemical and hematological parameters has been carried out in Senegal. The aim of the present study is therefore to evaluate the influence of diets containing different levels of this CAP on the biochemical and hematological parameters of local pigs fed *ad libitum* with these diets on station in the Casamance region of Senegal.

2. Materials and Methods

2.1. Areas and Period of Study

This study was carried out in a piggery located at Bona in the Bounkiling department (Figure 1), at Sédhiou region of Casamance, over a period of 112 days (December 2022 to April 2023). This region is bordered to the north by the Republic of Gambia, to the south by the Republic of Guinea Bissau, to the east by the Kolda region and to the west by the Ziguinchor region. It is characterized by a Sudano-Guinean climate with rainfall from June to October, peaking in August and September, and a dry season from November to May. Average rainfall ranges from 700 to 1300 mm. The lowest average monthly temperatures are recorded between December and January, ranging from 25 to 30°C, while the highest are recorded between March and September, with variations of 30 to 40°C. This climate is favorable to agro-sylvo-pastoral activities [9].

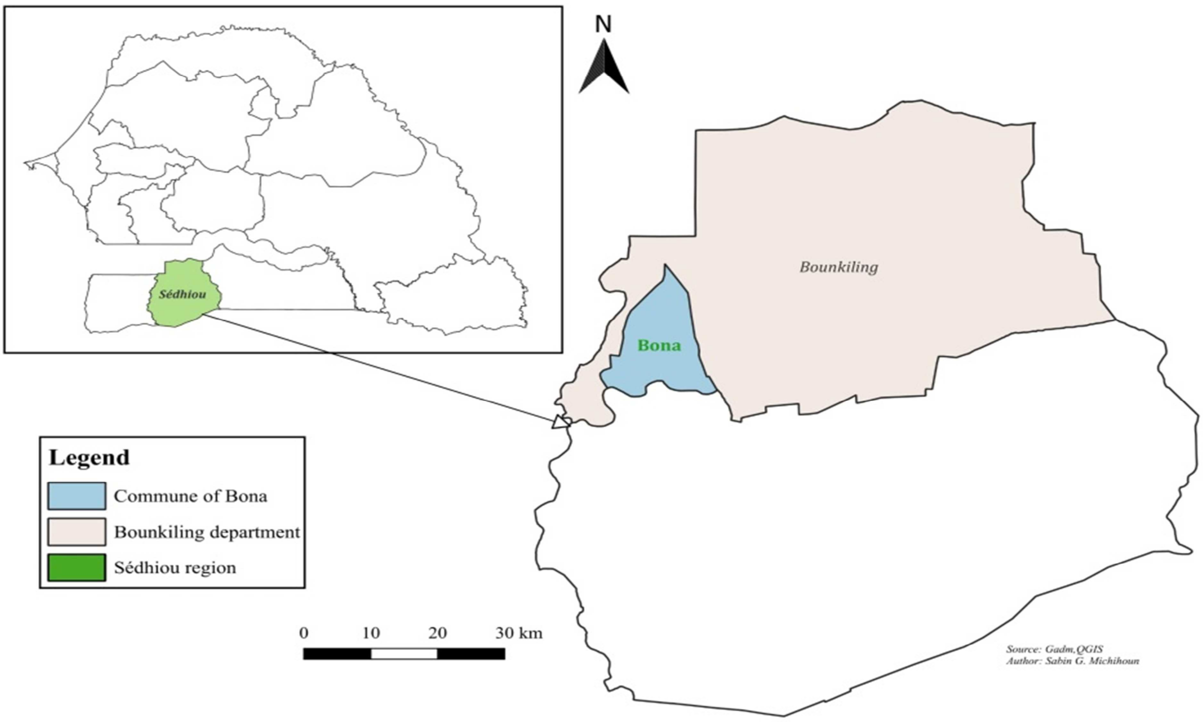

***Figure 1.** Localisation of Bona, the area of Study in Bounkiling department at Sedhiou region.*

2.2. Pigsty and Equipment Preparation

The pigsty used is of the semi-open type, built of brick and unplaster, with a single-slope zinc roof supported by a wooden framework. It comprises 12 pens, each averaging 3.9 m in length and 2.5 m in width (i.e. a surface area of 9.75 m^2), with low walls approximately 1.2 m high. The floor is concreted, and each stall is equipped with wooden feeders and drinkers (hollowed-out tree trunks). Two weeks before starting the trial, the barn was emptied, swept, cleaned with soapy water for the first four days and disinfected with bleach on day 5. Similarly, all rearing equipment (feeders, troughs) was washed and disinfected with bleach. A second disinfection of the barn and rearing equipment was carried out three days before starting the trial, and a compulsory disinfection foot bath was installed at the entrance to the barn.

2.3. Experimental Diets and Proximate Analysis

Cashew apple pulp (CAP) - residues from cashew apples after juice extraction - and the other feed resources used (table 1) in the experimental diets were purchased on the local market of Casamance, with the exception of oyster shell meal and additives (vitamin and mineral complex - MVC, synthetic lysine and methionine), which were bought in Dakar. Based on the nutritional values of these ingredients, which are well known to pig farmers, and the interesting preliminary digestibility results of diets based on dried CAP [10], four isoproteic and iso-energetic growth-finishing diets for pigs were formulated, including the control diet, CAP_0 and three others CAP_{10}, CAP_{15} and CAP_{20} containing respectively 0, 10, 15 and 20% of this CAP in partial substitution of the main feed sources of energy, protein and fiber in the diets. Around seven (7) tons of these diets were manually produced on the farm, packed in polypropylene bags. Samples of CAP and experimental diets were analyzed at the Laboratoire d'Analyses des Aliments et de Nutrition Animales (LANA) of the Ecole Inter-Etats des Sciences et Médecine Vétérinaires (EISMV) in Dakar. These analyses were focus on the determination of dry matter (DM), ether extract (EE), ash, crude protein (CP), crude fiber (CF), calcium, phosphorus and digestible energy (DE) contents. The DM was determined according to AFNOR's study [11] and the crude ash content was based on AFNOR's study [12]. The CP content was determined according to the same standard, but based on Kjeldhal method, using N*6.25 AFNOR's study [13], while EE was determined using the reflux extraction method with diethyl ether using the Soxhlet apparatus, described by AFNOR's study [14]. The crude fiber content was found according to AFNOR's study [15] based on the Wende method. The calcium content was measured using the flame atomic absorption spectrophotometric method of AFNOR's study [16], while phosphorus content was measured using the absorption spectrophotometric method at 430 nm of wavelength as described by AFNOR's study [17]. The DE content of the different feed samples was calculated according to the regression equation of Noblet's study [18]: [DE (MJ/kg DM) = 17.37 - 0.051 Ash + 0.01CP + 0.016EE - 0.027CF]. The ingredients composition and calculated nutritive value of these experimental diets are reported in table 1.

Table 1. *Raw materials composition and nutrient values of diets containing 0 (CAP_0), 10 (CAP_{10}) 15 (CAP_{15}) and 20% (CAP_{20}) of dried cashew apple pulp (CAP) used in pigs during the trial.*

Raw materials	**Diet control**	**Diets based on CAP**		
	CAP_0	**CAP_{10}**	**CAP_{15}**	**CAP_{20}**
Maize	49.25	43.20	42.40	41.60
Rice bran	28.50	28.06	25.02	22.00
Groundnut cake	10.00	8.50	7.62	7.00
Palm kernel cake	10.00	8.25	7.62	7.00
Dried cashew apple pulp (CAP)	0.00	10.00	15.00	20.00
L-Lysine (99%)	0.25	0.34	0.39	0.43
DL-Methionine (98%)	0.00	0.00	0.04	0.07
Natural limestone	1.50	1.40	1.40	1.40
MVC*-fattening (0.5%)	0.50	0.50	0.50	0.50
Total	100	100	100	100
Nutrient values				
Dry matter (%)	90.95	90.04	90.22	90.50
Crude protein (%)	15.70	15.50	15.60	15.40
Ether extract (%)	4.57	3.73	4.52	4.25
Crude fiber (%)	10.53	8.84	9.26	8.42
Ash (%)	6.6	6.9	6.67	7.12
Nitrogen free extract	53.55	55.07	54.17	55.31
Calcium (%)	1.35	1.70	1.41	1.63
Phosphorus (%)	0.07	0.07	0.07	0.07
Digestible energy, DE (kcal/g)	3.352	3.288	3.304	3.324
DE/Crude protein (kcal/g)	21.35	21.21	21.18	21.58

(*) MVC: vitamin and mineral complex.

2.4. Animals and Experimental Setup

The experiment was undertaken in the full respect of ethic and animal care according to all procedures approved by the Ethics and Animal Welfare Committees of the Ecole Inter-Etats des Sciences et Médecine Vétérinaires (EISMV) of Dakar. Its set-up consisted of 84 local piglets aged 3 to 5 months (including 39 castrated males and 45 females) acquired in several localities in the Sédhiou region and weighing an average of 11 kg live body weight. These piglets were evenly distributed according to live body weight and sex into 4 batches of 21 subjects each, subdivided into 3 replicates of 7 subjects, corresponding respectively to the four previous dietary treatments for fattening pigs, CAP_0 (control), CAP_{10}, CAP_{15} and CAP_{20} containing respectively 0, 10, 15 and 20% of CAP. The trial was conducted in two successive phases: an adaptation and experimental phases. During the first phase, which lasted 12 days, all piglets were adapted to their new environment and different diets. They were also identified by ear tags, and dewormed with *Ivermectin 1%* subcutaneously at 0.3 ml/10 kg live body weight and *Levamisole* orally at one bolus per 50 kg live body weight. This deworming was repeated one month later. They also received intramuscular fortifying products based on amino acids (lysine and glycine), trace elements (iron and cobalt) and vitamins (A, D_3, E, B_1, B_3, B_5, B_6, B_{12} and PP). The usual control diet was progressively replaced by the CAP-based diets CAP_{10}, CAP_{15} and CAP_{20}, thus determining the amount of feed to be fed to the pigs during the experimental phase. All male pigs were castrated to avoid the occurrence of early pregnancies during the trial. During the 112-days trial, all piglets were kept in permanent confinement and reared at an average density of 1.4 m^2/subject. They were fed *ad libitum* with only mealy diets (CAP_0, CAP_{10}, CAP_{15} and CAP_{20}) produced for this purpose in wooden troughs. Before distributing, diets were slightly wetted to facilitate their consumption by the animals. The quantities of feed distributed are readjusted weekly to limit refusal diets. Drinking water is also supplied *ad libitum* in the same type as the feed troughs. Stalls, troughs and feed troughs were cleaned daily with water, then washed with soapy water and disinfected with bleach twice a week, with access to the barn well regulated.

2.5. Data Collection

From a zootechnical standpoint, during the trial, ambient parameters (temperature and hygrometry) in the barn were regularly recorded three times a day (morning, noon and evening) using thermo-hygrometers, as others parameters such as live weight, feed intake and pig mortality. The mortality and feed intake were monitored on daily basis, while individual body live weights of pigs were taken every two weeks on an empty stomach using a portable electronic weighing scale with a maximum capacity of 50 kg and 100 g precision, or of 100 kg and 200 g precision when pig's body weight exceeded the capacity of the first. On the eve of start-up (day-1), on days 60 and 112 of the trial, two blood samples (in dry and EDTA tubes respectively) were taken from each of the pigs batched according to the dietary feed, for a total of 504 samples. These blood samples were taken from the cranial vena cava, very early in the morning, from these pigs fasting for around 12 hours, in dry and Ethylene Diamine Tetra Acetic (EDTA) tubes. Samples taken from dry tubes were immediately centrifuged by hand, with the sera collected in Eppendorf-type microtubes. These serum microtubes, together with blood samples in EDTA tubes, were stored in a cool box using carboglass, then transported after 24 hours to the Laboratoire d'endocrinologie, de radio-immunologie et de biologie moléculaire (LERBIOM) at EISMV in Dakar.

2.6. Biochemical et Hematological Analysis of Blood Samples

The biochemical analyses included the determination of total protein, albumin, urea, creatinine, glucose, cholesterol, phosphorus, calcium, magnesium, alanine aminotransferase (ALAT) and aspartate aminotransferase (ASAT) according to well-defined assay principles. The total plasma protein and albumin values were respectively determined spectrophotometrically using the Biuret reaction at 546 nm according to Gornall et al. [19] and the bromocresol green reaction described by Doumas et al. [20] at 670 nm wavelength. The Urea and creatinine were respectively determined spectrophotometrically using the urease reaction of Searcy et al. [21] at 600 nm and the Jaffé reaction of Mazzachi et al. [22] at 505 nm wavelength. The glucose and cholesterol were respectively determined spectrophotometrically using glucose oxidase method according to Trinder [23] and coupled cholesterol esterase and cholesterol oxidase reactions reported by Allain et al. [24] at 505 nm wavelength. The calcium was determined by the methylthymol blue method without deproteinization of Gindler and King [25] at 600 nm wavelength. The phosphorus and magnesium were determined by forming a phosphomolybdic complex in the presence of ferrous sulfate and a colored complex with calmagite in an intermediate alkaline medium, quantifiable by spectrophotometer at wavelengths of 340 nm described by Gamstand Try [26] and 505 nm of Barboun and Davisdon [27] respectively. The ALAT and ASAT values were determined spectrophotometrically using coupled lactate dehydrogenase and malate dehydrogenase reactions respectively, at 340 nm wavelength according Gella et al. [28].

The hematological analysis consisted of blood counts or hemograms of the various blood samples taken on EDTA tubes. These analyses were carried out immediately using an automated device, and included determination of the number of red blood cells (RBC), white blood cells (WBC), lymphocytes (Lym), monocytes (Mon), neutrophils (Neu), eosinophils (Eos), basophils (Bas) and platelets (Plt), hemoglobin (HB), hematocrit (HCT), average corpuscular volume (ACV), average corpuscular hemoglobin concentration (ACHC), average corpuscular hemoglobin content (ACH), red blood cell distribution index (RCI) and average platelet volume (APV).

2.7. Zootechnical and Haematological Parameters Determination

The data collected was recorded in Microsoft Excel spreadsheet (version 2010), which was used to calculate the zootechnical (average body live weight - ALW, daily feed intake - FI, average daily weight gain - ADWG, feed conversion ratio – FCR) and hematological (Average corpuscular volume - ACV, Average corpuscular in hemoglobin concentration - ACHC, Average corpuscular in hemoglobin content - ACH, Red blood cells reduction index (%) - RCI, Average platelet volume - APV), parameters for each dietary treatment in the same way, according to the formulas below:

$$ALW\ (kg) = Sum\ of\ live\ weights\ of\ individuals\ in\ the\ same\ batch\ \div\ Batch\ size \quad (1)$$

DFI $((g/pig/d)$= (Quantity of feed served/day- Quantity of feed refused/day)÷ Number of pigs (2)

$$ADWG\ (g/d) = [Weight\ gain\ achieved\ during\ a\ period\ (g)\ \div\ Length\ of\ period\ (days)] \quad (3)$$

$$FCR = \text{Feed intake during period (g)} \div \text{Weight gain achieved during period (g)} \quad (4)$$

$$ACV\ (fL) = [HCT\ (\%) * 10\ /\ number\ of\ red\ blood\ cells\ (in\ millions/mm3)] \quad (5)$$

$$CCMH\ (g/100\ mL) = [HB\ (g/100\ mL) * 100\ /\ HCT\ (\%)] \quad (6)$$

$$ACH\ (pg) = [HB\ (g/100\ mL) * 10\ /\ number\ of\ red\ blood\ cells\ (in\ millions/mm3)] \quad (7)$$

$$RCI\ (\%) = [(deviation\ standard\ of\ ACV/\ ACV) * 100] \quad (8)$$

$$A\text{verage blood element content} = \text{sum of batch contents} \div \text{number of subjects sampled in the batch} \quad (9)$$

2.8. Statistical Analysis

Data obtained including those calculated in the Microsoft Excel 2010 spreadsheet per dietary treatment, were exported to the IBM Statistical Package for the Social Science (SPSS-v.23), where they were subjected to ANOVA one-way factor analysis test, completed by the DUNCAN's post-hoc test when the first showed significant difference between means of dietary treatments at 5% threshold. The Student's t-test of the same software was also used to compare the averages of biochemical and hematological parameters obtained in all pigs of the different batches before the start of the trial with those obtained in subjects fed each of the CAP-based diets during the experiment.

3. Results

3.1. Environmental Parameters and Pig Mortality Recorded During the Trial

During the trial period, ambient temperature and humidity in the study area varied from 16.8 to 42.4°C and from 19 to 73% respectively. The highest temperatures were recorded in the middle of the day and in the evening, while the lowest were recorded in the morning in contrary the levels of humidity. Overall, the average temperature and humidity during the trial period were 32.5°C and 39% respectively. Throughout the trial, no real illnesses were recorded, besides from a few cases of temporary inappetence, some of which were brought under control by vitamin therapy. On the other hand, mortality per diet was recorded in pigs fed CAP_0, CAP_{10}, CAP_{15} versus no mortality in pigs fed CAP_{20}, i.e. a mortality rate of 4.7% vs. 0% respectively. The incorporation of CAP into the pigs' dietary treatments had no adverse effect on their health and mortality during the trial, with an overall mortality rate of 3.5%.

3.2. Growth-Weaning Performance of Local Pigs Fed Diets Based on Dried Cashew Apple Pulp (CAP) Meal

The parameters recorded in pigs during the trial, including body live weight, individual feed intake (FI) and feed conversion ratio (FCR) per diet, are shown in table 2. It was noted at the end of the trial that incorporating dried CAP into the diet of growing-finishing pigs had no adverse effect ($p > 0.05$) on their body live weights (BLW), and produced pigs with similar average LW overall, with an average of 34.9 kg. Over the entire duration of the trial, pigs' ADWG between the different dietary treatments followed the same trend as their LW, with an overall ADWG equal to 206.3 g/d. The pigs on CAP_0 and CAP_{15} diets (1010.9 g/d) intaked significantly more feed, followed by those on CAP_{10} (963.1 g/d) and CAP_{20} (906.3 g/d) diets respectively during the trial period. As for feed conversion ratio (FCR), it was noted during the experimental period that the incorporation of CAP into the pigs' diet significantly reduced feed conversion ratio in these subjects compared to that of control subjects. Indeed, pigs fed CAP_{10} and CAP_{20} diets significantly recorded the best but similar FCR (≈ 5), followed respectively by those fed CAP_{15} (5.6) and CAP_0 (6) diets. For all experimental subjects, overall, the average FI and FCR of pigs during the trial were 972.8 g/pig/d and 5.4, respectively.

Table 2. *Effect on body live weight (BLW), average daily weight gain (ADWG), feed intake (DFI) and feed conversion ratio (FCR) of pigs fed diets containing 0 (CAP_0), 10 (CAP_{10}), 15 (CAP_{15}) and 20% (CAP_{20}) dried cashew apple pulp.*

Zootechnics parameters	Dietary treatments (experimental diets)				*p*-Value
	CAP_0	CAP_{10}	CAP_{15}	CAP_{20}	
Initial BLW (kg)	11±	11±	11±	11.2±	0.62
Final BLW (kg)	33.5±	36.5±	35.1 ±	34.5 ±	0.70
ADWG (g/d)	197.4 ± 40.5	220.6 ± 65.4	205.4 ± 37.7	201.8 ± 62	0.52
DFI (g/pig/d)	1,033.9 ± 113.4^b	963.1 ± 68.2^{ab}	987.9 ± 29.8^b	906.3 ± 173.3^a	0.00
FCR	6 ± 1.5^b	5.1 ± 1.1^a	5.6 ± 1.6^{ab}	4.9 ± 1.1^a	0.03

a, b: the average with distinct letters are significantly different on the same line ($p < 0.05$).

3.3. Biochemical Parameters Obtained in Pigs Fed Diets Based on Dried Cashew Apple Pulp (CAP)

The results of the serum biochemical profile obtained in the pigs are presented in tables 3 and 4. The comparison of the averages of biochemical parameters obtained in pigs fed each of the CAP-based diets during the trial with those recorded in all these pigs prior to the start of the trial (table 3), shows that incorporation of dried CAP into the feed ration of growing-finishing pigs, significantly decreased proteinemia, albuminemia and phosphatemia in pigs in contrast to creatininemia, ALAT content and calcemia. In addition, cholesterol and magnesium levels were reduced in pigs fed CAP_{10} and CAP_{15} respectively, while blood glucose and magnesium levels were reduced in pigs fed CAP_{15} and CAP_{20} respectively. The table 4 shows that albumin and uremia levels were similar ($p>0.05$) between pigs fed the different treatments, with mean levels of 27.7 g/L and 6.1 mmol/L respectively. However, the incorporation of CAP into the feed diet of growing-finishing pigs significantly reduced total protein and AST levels compared with those (84.1 g/L, 49.1 and 44 U/L) of the control diet, while ALAT blood levels did not. In fact, pigs fed CAP_{20} (79.9 g/L, 33.5 and 48.3 U/L) and CAP_{10} (79.2 g/L, 29.3 and 57.2 U/L) diets recorded the highest protein levels compared to those fed CAP_{15} (74.5 g/L, 40.5 and 60.1 U/L), in contrast to blood levels of ASAT and ALAT transaminases. The cholesterol and magnesium levels were significantly higher in pigs fed diets CAP_{15} (2.8 and 4 mmol/L) and CAP_{20} (2.8 and 5.2 mmol/L), followed by those fed diets CAP_0 (2.6 and 3.8 mmol/L) and CAP_{10} (2.4 and 3.4 mmol/L) respectively. The creatinine and phosphorus levels were also significantly higher in pigs fed diets CAP_{20} (147.3 µmol/L, 14.4 and 3.6 mmol/L) and CAP_{10} (139.3 µmol/L, 12.4 and 4, 1 mmol/L), followed by pigs fed CAP_0 (136.1µmol/L, 12.5 and 4.8 mmol/L) and CAP_{15} (128.6 µmol/L, 9.6 and 4.4 mmol/L) respectively, in contrast to blood glucose levels. In addition, pigs fed diet CAP_{20} (15.5 mmol/L) had higher blood calcium levels, followed respectively by those (14.3; 13.6 and 12.5 mmol/L) fed diets CAP_0, CAP_{10} and CAP_{15}.

Table 3. *Biochemical parameters obtained in local pigs not yet fed (control) and fed diets containing 10 (CAP_{10}) 15 (CAP_{15}) and 20% (CAP_{20}) dried cashew apple pulp (CAP) in the Sédhiou region.*

Biochemical parameters	**Reference value****	**Control* (n= 84)**	**CAP_{10} (n= 21)**	***p-Value* (0.05)**	**CAP_{15} (n= 21)**	***p-Value* (0.05)**	**CAP_{20} (n= 21)**	***p-Value* (0.05)**
Total protein (g/L)	[48 - 103]	88.2 ± 9.5^{b}	79.2 ± 12.4^{a}	0.000	74.5 ± 8.1^{a}	0.000	79.9 ± 11.7^{a}	0.001
Albumin (g/L)	[18 - 56]	39.5 ± 7.1^{b}	28.5 ± 4.5^{a}	0.000	26.4 ± 2.8^{a}	0.000	27.4 ± 5.2^{a}	0.000
Aspartate aminotransferase (U/L)	[20.4 - 107.7]	34.1 ± 12.7^{a}	29.3 ± 5.8^{a}	0.089	40.4 ± 8.6^{b}	0.034	33.5 ± 4^{a}	0.826
Alanine aminotransferase (U/L)	[10 - 60.1]	39.5 ± 11.5^{a}	57.2 ± 20.8^{b}	0.000	60.1 ± 19.4^{b}	0.000	48.3 ± 11^{b}	0.002
Creatinine (µmol/L)	[75.1 - 230]	94.9 ± 14.4^{a}	139.3 ± 11^{b}	0.000	128.6 ± 15.4^{b}	0.000	147.3 ± 13.5^{b}	0.000
Urea (mmol/L)	[1.4 - 8]	6.4 ± 0.9^{b}	6.2 ± 0.9^{b}	0.510	5.9 ± 1.1^{a}	0.038	6.4 ± 0.9^{b}	0.972
Cholesterol (mmol/L)	[1.5 - 4.5]	3 ± 0.8^{b}	2.4 ± 0.3^{a}	0.001	2.8 ± 0.5^{b}	0.360	2.8 ± 0.4^{b}	0.347
Glucose (mmol/L)	[1.1 - 7.5]	3.5 ± 1.7^{a}	4.1 ± 0.8^{a}	0.101	4.4 ± 1.2^{b}	0.019	3.6 ± 1^{a}	0.900
Calcium (mmol/L)	[1.9 - 3.3]	10.7 ± 1.7^{a}	13.6 ± 1.4^{b}	0.000	12.5 ± 1.9^{b}	0.000	15.5 ± 2.1^{b}	0.000
Phosphorus (mmol/L)	[1.7 - 3.5]	16.1 ± 3.3^{b}	12.4 ± 5.3^{a}	0.000	9.6 ± 2.8^{a}	0.000	14.4 ± 2.8^{a}	0.000
Magnesium (mmol/L)	[0.5 - 1.5]	4.7 ± 1^{b}	3.4 ± 0.4^{a}	0.000	4 ± 0.8^{a}	0.006	5.2 ± 0.9^{c}	0.000

a, b, c: the average with distinct letters are significantly different on the same line ($p<0.05$)

(*): Average values obtained in all local pigs before experimentation

(**): References values synthesis of pig's biochemical parameters [34-44, 49]

Table 4. *Biochemical parameters obtained in local pigs fed diets containing 10 (CAP_{10}) 15 (CAP_{15}) and 20% (CAP_{20}) dried cashew apple pulp (CAP) in the Sédhiou region.*

Biochemical parameters	**Dietary treatments (experimental diets)**				**Reference value**	***p*-Value (0.05)**
	$CAP_{0\ (n=21)}$	**$CAP_{10\ (n=21)}$**	**$CAP_{15\ (n=21)}$**	**$CAP_{20\ (n=21)}$**		
Total protein (g/L)	84.1 ± 8.2^{b}	79.2 ± 12.4^{ab}	74.5 ± 8.1^{a}	79.9 ± 11.7^{ab}	[48 - 103]	0.03
Albumin (g/L)	28.5 ± 2.7	28.5 ± 4.5	26.4 ± 2.8	27.4 ± 5.2	[18 - 56]	0.26
Aspartate aminotransferase (U/L)	49.1 ± 30.1^{c}	29.3 ± 5.8^{a}	40.4 ± 8.6^{b}	33.5 ± 4^{ab}	[20.4 - 107.7]	0.00
Alanine aminotransferase (U/L)	44.0 ± 12.4^{a}	57.2 ± 20.8^{b}	60.1 ± 19.4^{c}	48.3 ± 11^{ab}	[10 - 60.1]	0.00
Creatinine (µmol/L)	136.1 ± 10.1^{ab}	139.3 ± 11^{b}	128.6 ± 15.4^{a}	147.3 ± 13.5^{c}	[75.1 - 230]	0.00
Urea (mmol/L)	5.8 ± 1.1	6.2 ± 0.9	5.9 ± 1.1	6.4 ± 0.9	[1.4 - 8]	0.22
Cholesterol (mmol/L)	2.6 ± 0.5^{ab}	2.4 ± 0.3^{a}	2.8 ± 0.5^{b}	2.8 ± 0.4^{b}	[1.5 - 4.5]	0.01
Glucose (mmol/L)	4.8 ± 0.6^{c}	4.1 ± 0.8^{b}	4.4 ± 1.2^{bc}	3.6 ± 1^{a}	[1.1 - 7.5]	0.00
Calcium (mmol/L)	14.3 ± 2.5^{bc}	13.6 ± 1.4^{ab}	12.5 ± 1.9^{a}	15.5 ± 2.1^{c}	[1.9 - 3.3]	0.00
Phosphorus (mmol/L)	12.5 ± 4.8^{b}	12.4 ± 5.3^{b}	9.6 ± 2.8^{a}	14.4 ± 2.8^{b}	[1.7 - 3.5]	0.00
Magnesium (mmol/L)	3.8 ± 0.8^{ab}	3.4 ± 0.4^{a}	4 ± 0.8^{b}	5.2 ± 0.9^{c}	[0.5 - 1.5]	0.00

a, b, c: the average with distinct letters are significantly different on the same line ($p< 0.05$)

3.4. Hematological Parameters Obtained in Pigs Fed Diets Based on Dried Cashew Apple Pulp (CAP)

The results of the hematological profile obtained in the pigs are presented in tables 5 and 6. The comparison of the mean hematological parameters obtained in pigs on each of the CAP-based diets during the trial with those recorded in all pigs prior to the start of the trial (table 5) clearly shows that incorporation of CAP into the feed ration of growing-finishing pigs significantly reduced the proportion of basophils, ACH, ACHC and RCI in pigs, in contrast to HB, APV, HCT, the proportion of monocyte and the number of red blood cell (RBC). In addition, this incorporation resulted in a decrease in neutrophils, platelets and mean corpuscular volume; white blood cells and lymphocytes; and neutrophils respectively in pigs fed diets CAP_{15}, CAP_{10} and CAP_{20}, in contrast to neutrophil and lymphocyte counts respectively in pigs fed diets CAP_{10} and CAP_{20}.

The table 6 shows the proportions of monocytes (Mon) and basophils (Bas), the number of red blood cells (RBC), hemoglobin concentrations (HB), hematocrit levels (HCT), mean corpuscular hemoglobin content (ACH), red cell distribution indices (RCI) and average platelet volumes (APV) were similar (p>0.05) between the different dietary treatments, with mean values of 7.33 and 0.16% respectively; 7.66 x1012 /L; 141 g/L; 50.9%; 18.4 pg; 19.2% and 10.7 fL respectively. A significantly higher white blood cell (WBC) count was observed in pigs fed CAP_{20} (10.99 x109/L), followed respectively by those fed CAP_{10} (9.95 x109/L), CAP_{15} (9.22 x109/L) and CAP_0 (5.99 x109/L), in contrast to the proportions of eosinophils (Eos). The proportion of neutrophils (Neu) was significantly higher in pigs fed CAP_{10} (38.55%), followed by those fed CAP_0 (33.21%), CAP_{15} (28.67%) and CAP_{20} (26%) respectively, in contrast to average corpuscular volume (ACV). The proportion of Lym was significantly higher in pigs fed CAP_{20} (62.71%), followed by those fed CAP_{15} (55.26%), CAP_0 (51.8%) and CAP_{10} (50.03%) respectively, in contrast to average corpuscular hemoglobin concentration (ACHC). The number of platelet cells was similar and significantly higher in pigs on diets CAP_{20} (261 x109/L) and CAP_0, followed respectively by those on diets CAP_{10} (245 x109/L) and CAP_{15} (207 x109/L).

Table 5. *Hematological parameters obtained in local pigs not yet fed (control) and fed diets containing 10 (CAP_{10}) 15 (CAP_{15}) and 20% (CAP_{20}) dried cashew apple pulp (CAP) in the Sédhiou region.*

Hematological parameters	Reference value **	Control* (n= 84)	CAP10 (n= 21)	p-Value (0.05)	CAP15 (n= 21)	p-Value (0.05)	CAP20 (n= 21)	p-Value (0.05)
White blood cells (10^9/L)	[9.3 - 30]	12.44 ± 4.73^b	9.95 ± 2.68^a	0.022	9.22 ± 2.32^a	0.003	10.99 ± 2.10^b	0.173
Lymphocytes (%)	[37.8 - 73.6]	55.42 ± 7.23^b	50.03 ± 8.98^a	0.004	55.26 ± 8.84^b	0.931	62.71 ± 5.50^c	0.000
Monocytes (%)	[1 - 12]	4.07 ± 2.53^a	7.30 ± 1.31^b	0.000	6.99 ± 1.53^b	0.000	7.08 ± 1.35^b	0.000
Neutrophils (%)	[13.3 - 60]	34.24 ± 6.47^b	38.55 ± 8.30^c	0.012	28.67 ± 7.75^a	0.001	26 ± 5.68^a	0.000
Eosinophils (%)	[0 - 11]	3.82 ± 2.32	3.95 ± 1.58	0.808	4.74 ± 1.68	0.089	4,04 ± 1.36	0.674
Basophils (%)	[0 - 2]	0.77 ± 0.82^b	0.15 ± 0.07^a	0.001	0.16 ± 0.07^a	0.001	0.14 ± 0.07^a	0.001
Red blood cells_RBC (10^12/L)	[4.98 - 9]	7.07 ± 0.99^a	7.76 ± 1^b	0.005	7.55 ± 1.39^a	0.074	7.78 ± 0.59^b	0.002
Hemoglobin _HB (g/L)	[92.8 - 160]	125 ± 15^a	144 ± 18^b	0.000	137 ± 26^b	0.007	145 ± 14^b	0.000
Hematocrit (%)	[32.1 - 52]	41.4 ± 7.3^a	52.5 ± 7.3^b	0.000	48.4 ± 9.3^b	0.000	51.4 ± 5^b	0.000
Average corpuscular volume (fL)	[52 - 70]	68.2 ± 5.1^b	67.8 ± 3.5^b	0.719	64,3 ± 2,6^a	0.001	66 ± 2.7^b	0.058
Average corpuscular HB content (pg)	[16 - 23.01]	20.2 ± 2.2^b	18.6 ± 1^a	0.002	18.1 ± 0.7^a	0.000	18.5 ± 0.7^a	0.001
Average corpuscular HB concentration (g/L)	[265.8 - 350]	302 ± 22^b	276 ± 7^a	0.000	283 ± 4^a	0.000	282 ± 6^a	0.000
RBC reduction index (%)	[15 - 20]	19.8 ± 0.7^b	19.3 ± 1.4^a	0.028	19.2 ± 0.8^a	0.001	19.1 ± 0.8^a	0.000
Platelets (10^9/L)	[38.3 - 600]	262 ± 42^b	245 ± 62^b	0.147	207 ± 51^a	0.000	261 ± 78^b	0.924
Average platelet volume (fL)	[6.2 - 13.3]	9.6 ± 1.1^a	10.6 ± 0.8^b	0.000	10.8 ± 0.8^b	0.000	10.9 ± 0.8^b	0.000

a, b, c:: the average with distinct letters are significantly different on the same line (p< 0.05)

(*): Average values obtained in all local pigs before experimentation

(**): References values synthesis of pig's biochemical parameters [34-35, 37-38, 51-52]

Table 6. *Hematological parameters obtained in local pigs fed diets containing 0 (CAP_0), 10 (CAP_{10}) 15 (CAP_{15}) et 20% (CAP_{20}) dried cashew apple pulp (CAP) in the Sédhiou region.*

Hematological parameters	Dietary treatments (experimental diets)				Reference value	*p-Value (0.05)*
	$CAP_{0\ (n=21)}$	$CAP_{10\ (n=21)}$	$CAP_{15\ (n=21)}$	$CAP_{20\ (n=21)}$		
White blood cells_WBC (10^9/L)	5.99 ± 0.83^a	9.95 ± 2.68^{bc}	9.22 ± 232^b	10.99 ± 2.10^c	[9.3 - 30]	0.00
Lymphocytes _Lym (%)	51.80 ± 6.56^{ab}	50.03 ± 8.98^a	55.26 ± 8.84^b	62.71 ± 5.50^c	[37.8 - 73.6]	0.00
Monocytes_Mon (%)	7.95 ± 1.43	7.31 ± 1.31	6.99 ± 1.53	7.08 ± 1.35	[1 - 12]	0.12
Neutrophils_Neu (%)	33.21 ± 6.87^b	38.55 ± 8.30^c	28.67 ± 7.75^a	26 ± 5.68^a	[13.3 - 60]	0.00
Eosinophils_Eos (%)	6.85 ± 2.27^b	3.95 ± 1.58^a	4.74 ± 1.68^a	4.04 ± 1.36^a	[0 - 11]	0.00
Basophils_Bas (%)	0.18 ± 0.05	0.16 ± 0.07	0.16 ± 0.07	0.14 ± 0.07	[0 - 2]	0.20
Red blood cells_RBC (10^12/L)	7.55 ± 0.88	7.76 ± 1	7.55 ± 1.39	7.78 ± 0.59	[4.98 - 9]	0.79
Hemoglobin _HB (g/L)	140 ± 17	144 ± 18	137 ± 26	145 ± 14	[92.8 - 160]	0.50
Hematocrit_HCT (%)	51.4 ± 6.3	52.5 ± 7.3	48.4 ± 9.3	51.4 ± 5.0	[32.1 - 52]	0.30
Average corpuscular volume_ ACV (fL)	67.9 ± 1.9^b	67.8 ± 3.5^b	64.3 ± 2.6^a	66 ± 2.7^a	[52 - 70]	0.00
Average corpuscular hemoglobin content_ACH (pg)	18.5 ± 0.5	18.6 ± 1	18.1 ± 0.7	18.5 ± 0.7	[16 - 23.01]	0.13
Average corpuscular hemoglobin concentration_ACHC (g/L)	273 ± 7^a	276 ± 7^a	283 ± 4^b	282 ± 6^b	[265.8 - 350]	0.00
RBC reduction index (%)	19.2 ± 0.7	19.3 ± 1.4	19.2 ± 0.8	19.1 ± 0.8	[15 - 20]	0.85
Platelets cells (10^9/L)	285 ± 70^b	245 ± 62^{ab}	207 ± 51^a	261 ± 78^b	[38.3 - 600]	0.00
Average platelet volume _APV (fL)	10.5 ± 0.7	10.6 ± 0.8	10.8 ± 0.8	10.9 ± 0.8	[6.2 - 13.3]	0.21

a, b, c: the average with distinct letters are significantly different on the same line (p<0.05)

4. Discussion

The average ambient temperature recorded in the study area (32.5°C) was still higher than that recorded (29.3°C) by Ossebi et al. [2] and the limit of 30°C below which local pigs could express their growth potential [29]. The high temperature recorded during the trial could be explained by the fact that the trial took place during a hot period when temperatures varied between 16.8 and 42.4°C. The low variation in hygrometry (39%) compared with that (74%) of Ossebi et al. [2] in the area may be due to the trial taking place at the end of the rainy seasons and during the dry season.

The low overall mortality rate recorded (3.5%) in pigs during the trial is thought to be due to the ongoing improvement in hygiene conditions and compliance with husbandry standards, which reduced microbial loads in the pigsty and preserved the animals from disease. However, these recorded mortalities could be the consequence of inappetence. This overall mortality rate remains higher than that (2%) of Ossebi et al. [2], due to their larger number of pigs (102). The absence of cases of disease in the pig's dietary treatments, indicating that the feed used had no adverse effect on their health, is in line with the observations of Oddoye et al. [6] and Armah[7] in Ghana.

The similarity of the pigs' average body live weights noted at the end of the trial between the different dietary treatment could be explained by their equal initial average body live weights, the same rearing conditions and the nutrient composition of the diets, which overall remained similar. The final average body live weight obtained (34.9 kg) in this trial is higher than that obtained (29.9 kg) by Ossebi et al. [2] with a diet containing 15% dried cashew apple pulp (CAP). This difference may be due to the duration of fattening, the quality of the diets used, the method of monitoring the pigs and the rigour of husbandry. Indeed, during the latter authors' trial, the pigs were monitored by the farmers themselves and fed a 13.5% crude protein diet for 90 days. The lower final mean body live weights than those obtained by Armah [7] in Ghana and Acero et al. [30] in the Philippines are due to the difference in breeds used, the initial weight of piglets at the start of fattening and the duration of the trial. In fact, the latter authors used Large White and Landrace x Large White mixed-breed whole male piglets whose initial live weights (13.3 and 10.87 kg) were higher than those of our local breed pigs.

Furthermore, the overall ADWG (206.3 g/d) recorded in the pigs is lower than the range observed (209.6 - 360 g/d) in several studies conducted under traditional and improved conditions in low-income countries [2, 6-7, 30]. In most of these studies, CAP was fed to pigs at a rate of 15-20%. However, the ADWG obtained in pigs is higher than those recorded by Hedji et al. [31] in Benin (103.6 g/day), who used an improved to feed local pigs.

The high feed intake (FI) of pigs on CAP_0 (1033.9 g/d) and CAP_{15} (987.9 g/d) diets compared to that recorded subjects on CAP_{10} and CAP_{20} diets could be attributed to their higher fiber contents (10.53 and 9.26% vs. 8.84 and 8.42%). Farias et al. [32] had justified this increase in FI of CAP_0 and CAP_{15} pig diets by a compensatory phenomenon of possible nutritional deficiencies, due to reduced nutrient utilization in high-fiber diets. In fact, high-fiber diets lead to increased desquamation of the intestinal mucosa and production of mucus, limiting the absorption of nutrients from higher-fiber diets and increasing peristaltic movements, thus limiting the permanence of nutrients in the pigs' intestinal tract. The low overall feed intake recorded (972.8 g/d/pig) in pigs compared with that (1,107 g/d/pig) of Ossebi et al. [2] could be explained by the high heat (32.5°C) recorded during our trial, in contrast to the work of these authors, which took place during the rainy season when the average ambient temperature was 29.3°C. This overall feed intake remains lower than those reported by Mopate [33] in Chad (1,143 g/pig/day) for local pigs, Oddoye et al. [6] andArmah [7] respectively for Large White pigs in Ghana (1,780 and 1,350 g/pig/d). The better feed conversion ratio obtained with CAP_{10} and CAP_{20} diets (5) compared to CAP_0 and CAP_{15} could be explained by their lower feed intake and the higher mineral composition of their diets. The average conversion ratio recorded (5.4) is better than that obtained (5.7) by Ossebi et al. [2], but higher than those (5.02 and 4.36) respectively obtained by Oddoye et al. [6] and Armah [7].

The values obtained for the various biochemical parameters were almost all within the normal range reported for pigs by Zhang et al. [34] and Anonymous [35], except for the values for calcemia (12.5-15.5 vs. 1.9-3.3 mmol/L), phosphatemia (9.6-14.4 vs. 1.7-3.5 mmol/L) and magnesemia (3.4-5.2 vs. 0.5-1.5 mmol/L), which were above their physiological range reported in the literature. Furthermore, the lower serum total protein concentrations (74.5 - 79.9 vs. 84.1 g/L) obtained in pigs fed CAP-based diets in this trial could be linked to the relatively lower crude protein content of these diets compared to that of the control diet (15.4-15.6 vs. 15.7%). In fact, the amount of dietary protein seems to be a major but not exclusive indicator of serum protein and albumin levels. It has also been shown that the physiological state of the animals and nutrient interactions could influence serum protein and other metabolites [36]. The overall mean value obtained for total protein concentration (79.4 g/L) is close to that (80.38 g/L) reported by Adegun et al. [37] in pigs fed diets based on *Moringa oleifera* and *Azadirachta indica* leaf meal. However, this value is well above those reported (53-69.32 g/L) in various studies [36, 38-42]. The ALAT and ASAT transaminases, mainly present in the liver and involved in amino acid metabolism, are well-known diagnostic indicators of liver damage [43]. The increase in ALAT (55.2 vs. 44 U/L) and decrease in ASAT (34.4 vs. 49.1 U/L) recorded in pigs fed CAP-based diets compared with the respective levels obtained in pigs on control diets, but with levels within the physiological range suggest that these pigs were free of myocardial infarction and skeletal muscle disorders, and that their livers and other organs were functioning well [41, 44]. The similarly higher cholesterol level (2.8 mmol/L) in pigs fed CAP_{15} and CAP_{20} diets was a direct result of the availability of dietary components, particularly lipids, as reported by Franczak et al. [45]. This value obtained is within the physiological range and close to those (2.53 mmol/L and 2.94 mmol/L) reported respectively by Akinduro et al. [41] and Adegun et al. [37]. Indeed, the normal cholesterol range indicates that the animal is not at risk of hypercholesterolemia and liver failure, and there is normal lipid mobilization and lipogenesis in the pig's body as the reduction in serum cholesterol suggests a general decrease in lipid mobilization in the animal's body [43]. The higher serum creatinine level in pigs fed the CAP_{20} diet (147.3 µmol/L), but within the physiological range, suggests that there was no muscle tissue wasting or catabolism, and that these pigs were not surviving at the expense of body reserves [46]. This may be due to better utilization of dietary protein by the pigs, since according to Ranjhan [47], when a diet is deficient in amino acids, the available amino acid will be deaminated, resulting in increased urea excretion. The creatinine values observed prove that the incorporation of CAP into the pigs' diet did not cause any damage to their kidneys, especially as serum urea values were within the physiological range and almost similar in all pigs on the different dietary treatments [48]. The higher blood glucose levels (4.8 mmol/L) obtained in pigs fed CAP_0 and CAP_{15} diets despite their higher crude fiber content (10.53 vs. 9.26%) could be explained by a high valorisation of these dietary fibers into easily fermentable carbohydrates by these pigs [36]. The significantly higher blood levels of calcium, phosphorus and magnesium (15.5; 14.4; 5.2 mmol/L) respectively in pigs fed the CAP_{20} diet could be the result of the mineral richness (7.12 vs. 6.6-6.9%) of this diet in contrast to the others. In pigs from the different treatments, the values recorded for these parameters are higher than those found in the literature [35, 39, 49]. This could also be explained by the age difference of these pigs, given that they are "off-the-shelf" subjects where the accuracy of their age is uncertain. Furthermore, according to Boyd et al. [50], piglets still under mother's care (suckling) undergo important physiological changes such as bone development, which will result in differences in parameters (i.e. high phosphorus concentration and alkaline phosphatase activity) compared to older growing pigs.

The values obtained for the various hematological parameters were almost all within the normal range reported for pigs, except for the white blood cell count obtained in pigs fed the control diet, which was below the norms reported in the literature [34-35, 37-38, 51-52]. The increase in the number of white blood cells obtained in pigs fed CAP_{15} and CAP_{20} diets, in particular lymphocytes, but within the physiological range, implies that these diets may have stimulated the cellular and humoral immune response systems of the pigs to protect them against the anti-nutritional factors according to Dudek et al. [53] of these diets or any infection compared with subjects in the control batch. These observations corroborate those reported by Serem et al. [54] in pigs fed *Moringa oleifera* leaf meal-based diets, and Okah and Ehuriah [36] in pigs subjected to *Bambara* weight waste-based diets. This increase could also be attributed to heat stress according to Buckham-Sporer et al. [55] and would be due to the mobilization of leukocytes from their pool to the peripheral circulation, apparently due to its inhibitory role on circulating corticosteroids which is known to increase in stressed animals and cause an increase in white blood cell numbers [56]. The higher proportion of neutrophils obtained in pigs fed the CAP_{10} diet, in contrast to those of eosinophils recorded in pigs fed all CAP-based diets but within the physiological range, would be a consequence of both an antimicrobial response and the absence of parasitic infections in these pigs during the experimental period [57-58]. The similarity of monocyte and basophil levels obtained in pigs fed the different diets but within the physiological range could indicate that the pigs did not react to any infection or hypersensitivity reaction related to the inclusion of CAP in these diets during this trial. The normal levels of HB, HCT, ACV, ACH and ACHC showed that the pigs did not suffer from anemia during this trial, and that their normal levels of platelet cells and APV would allow better coagulation of their blood in the event of injury.

5. Conclusion

Globally, this study showed that dried cashew apple pulp incorporated up to 20% into the pigs diet as substitution for energy, fiber and protein rich feed resources, had no adverse effect on their health status. Indeed, there are some variations between different dietary treatments for biochemical and hematological parameters studied, but the values of these latter are all in line with the corresponding reference values reported in pigs. However, regarding the significantly increase of white blood cells, particularly the lymphocytes, noted with the increasingly CAP levels in the diets, it would be useful to carry out a longer study on growing piglets by feeding them with diets containing more than 20% CAP in order to determine the maximum level of this feed resource incorporation which would not affect their health status and performances.

Authors' Contributions Statement and Agreement

This work was carried out in collaboration among all authors. All authors read and approved the final report.

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Conflicts of Interest

The authors declare no conflict of interest.

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