

Effect of Cassava Leaf (*Manihot esculenta*) Level in Guinea-Pigs (*Cavia porcellus*) Meal on the Physico-Chemical and Technological Properties of Its Meat

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Abstract

The present study was carried out to evaluate the effect of different rates of dried cassava leaves in diet as replacement of protein sources on the weight gain and carcass yield of guinea-pigs, as well as on the physico-chemical and technological properties of guinea-pigs' meat. A total of forty-eight (48) eight-week-old guinea-pigs were divided in a completely randomized experimental design, in four groups and fed with the experimental foods. These experimental foods were formulated as follows: cassava-leaf (*Manihot esculenta*) powder was incorporated at concentrations of 0%, 8%, 10% and 12% respectively in replacement of protein sources for R0, R1, R2 and R3. Each treatment consisted of a group of 12 guinea pigs per paddock (6 males and 6 females). The initial weight (IW), final weight (FW), daily weight gain (DWG) and total gain (TG) were evaluated. At the 22nd week, animals of each group were sacrificed by bleeding, then skinned and eviscerated. Carcasses were cut, and some parts (loin, thigh and shoulder) were collected, deboned and analysed. The highest FW and carcass yield (CY) were obtained with the use of 10% cassava leaves (R2): 556 g (FW), 42.65% (CY) for males and 529.17 g (FW), 37.39% (CY) for females. The incorporation of 8% (R1) and 12% (R3) cassava leaves led to a significant increase ($P < 0.05$) in protein levels in the loins (22.89%) and shoulders (22.43%) of females and the thighs (21.68%) and shoulders (21.09%) of males. However, protein levels of male fed with R3 in the various parts studied were higher than females fed with the same diet. The study of the technological parameters of guinea-pig's meat showed that the incorporation of 8% and 12% cassava leaves in the diet resulted in a significant decrease in the water holding capacity and technological yield in the different parts

studied. These results show that, the incorporation of cassava leafs in guinea-pigs' diet made it possible to obtain good growth (R2) and meat of good technological quality.

Keywords

Guinea Pigs, Diet, Cassava Leafs, Physico-Chemical Composition, Meat Technological Properties

1. Introduction

In developing countries, a majority of the population consists of farmers and breeders which depend on livestock for their survival [1]. However, the increasing lack of proteins due to increasing population size, poverty and lack of space for livestock is responsible for protein deficiencies such as protein-energy malnutrition (PEM). In some countries of sub-Saharan Africa, a bootjack solution is brought with mini-livestock; an activity in full expansion for ten years now, consists of rabbit breeding, hedgehog farming and cavies breeding [2]. In Latin America, the production of guinea pigs has been improved with the use of modern production practices. In Cameroon, production is mainly traditional where the animals scavenge on the floor for their daily needs [3]. Most food is provided from kitchen wastes and farm residues and sometimes supplemented with vegetables and forages. This has resulted in a situation where the productivity of these animals has remained low [4]. In addition, productivity concerns quantity as well as quality, and also reproduction. In order to ameliorate this situation, it is suitable to give these animals a diet that contains protein sources of high biological value such as soya bean meal. Due to the economic crisis affecting developing countries, it becomes more advisable to envisage the use of non-conventional sources of protein that are widely available [5], which may adequately and economically replace the traditionally used feed ingredients and allow economic viability of alternative guinea pigs systems. Indeed, cassava leafs, a by-product of cassava harvest is (depending on the varieties) rich in protein (14% - 40% dry matter), minerals, Vitamin (B1, B2, C) and carotenes [6]. In spite of these qualities, the nutritional potentials of cassava leaf meal and cassava protein concentrates remain currently under-researched [7].

Cassava leafs have been reported to have good amino acid content, comparable to soya bean meal, but are deficient in the sulphur-containing amino acids [8]. However, the most important limitation for the utilization of cassava leafs as feed for monogastric animals is probably its content of anti-nutritional factors (HCN and tannins) [9] and fibre [10]. However, Ravindran *et al.* [11] reported that simple sun-drying eliminates almost 90% of the initial cyanide content. The objective of this study is therefore, to evaluate the effects of the incorporation of cassava leafs at different rates in guinea-pigs' diet on the weight gain and carcass yield of guinea-pigs as well as on the physico-chemical and technological properties of the guinea-pig meat.

2. Materials and Methods

This study was conducted at the Animal Experimental Farm and in the "Biochemistry Laboratory of Medicinal Plants, Food Science and Nutrition" (LABPMAN) of the University of Dschang. Dschang is situated in the Western Highlands of Cameroon; its climate is of the Sudano-Guinean type. Its coordinates lie between *latitude* 5 North and *longitude* 10 East. Its mean daily temperature varies from 20°C to 28°C and its mean annual rainfall about 2000 mm.

2.1. Materials

2.1.1. Experimental Animals

Forty eight (8-week-old) local guinea pigs (*C. porcellus*) were used in this study. They were obtained from the Animal Experimental Farm of the University of Dschang. These animals were fairly homogenous in size and shape (86.98 ± 6.88 g). They were characterized by tri-colored coat pattern; of black and yellow pigmentation with varying degrees of spotting white.

2.1.2. Experimental Diets

Fresh cassava (*Manihot esculenta*) leafs were collected from the farm of the University of Dschang. The leafs

together with the petiole were thoroughly washed using tap water and rinsed with distilled water and sun-dried for 3 days after which, they were crushed and used to compose the experimental diets. Four experimental diets were prepared with graded concentration of cassava leaf inclusion and soya bean meal. The diets were as follows:

Diet 1 (R0): Control (0% cassava leaf and 6% soya bean meal)

Diet 2 (R1): Test (8% cassava leaf and 4% soya bean meal)

Diet 3 (R2): Test (10% cassava leaf and 2% soya bean meal)

Diet 4 (R3): Test (12% cassava leaf and 0% soya bean meal).

The percentage composition of these diets used in the study is shown in **Table 1**.

2.2. Methods

2.2.1. Trial Management

Forty eight guinea pigs (24 males and 24 females) at eight weeks old were divided randomly into four groups (each group containing 6 males and 6 females) corresponding to four levels of cassava leaf powder inclusion in their diets (0%, 8%, 10% and 12%). At the beginning of the study, animals were identified using small metallic ear tags bearing numbers.

2.2.2. Animal and Feeding Management

Animals were fed *ad libitum* with fresh forage mainly *Pennisetum purpureum* and supplemented daily with experimental diets. Moreover, water was also available *ad libitum*. Their cages were cleaned daily.

2.2.3. Animal Performance and Carcass Characteristics

The animals were weighed every 7 days at the same time of the day throughout the experimental period. Before slaughter, slaughter weight (used for the calculation of carcass yield), initial and final weights (used for the calculation of total weight gain and average of daily weight gain) were recorded. After slaughter, the carcasses were uniformly skinned, eviscerated and the weights of hot carcasses were recorded. The carcass yield was calculated as:

$$CY = \frac{\text{hot carcass weight}}{\text{slaughter weight}} \times 100$$

Table 1. Percentage composition of the experimental diets.

Ingredients	Diet (treatments)			
	R0	R1	R2	R3
Maize	31	44	45	45
Corn bran	48	31	30	28
soya bean meal	6	4	2	0
Cottonseed cake	2	1	1	2
Palm kernel crab	4	1	1	1
Fish meal	5	7	7	8
Bone meal	2	2	2	2
Salt	1	1	1	1
Premix 0.5%	1	1	1	1
Cassava-leaf meal	0	8	10	12
Total	100	100	100	100

Premix Composition 0.5%: Vit. A = 3,000,000 IU/kg. Vit. D3 = 600,000 IU/kg. Vit. E = 4000 mg/kg. Vit. K3 = 500 mg/kg. Vit. B1 = 200 mg/kg. VitB2 = 1000 mg/kg. Vit B3 = 2400 mg/kg. Biotin = 10 mg/kg. VitPP = 7000 mg/kg. Folic acid = 200 mg/kg. Cholin chloride = 10,000 mg/kg. Iron sulfate = 8000 mg/kg. Copper sulfate (II) = 2000 mg/kg. Manganese = 1400 mg/kg. Iodine = 200 mg/kg. Cobalt = 200 mg/kg. Selenium = 20 mg/kg. Méthionine = 20,000 mg/kg. Lysine = 78,000 mg/kg.

2.2.4. Muscle Samples Preparation

At the end of the study, the 12 animals (6 males and 6 females) per treatment were starved for a period of 12 hours and slaughtered by cervical dislocation for carcass weight evaluation. After this, the following three muscles: loin, thigh and shoulder were taken from the different carcasses. These muscles or samples were deboned before analysing the meat composition.

2.2.5. Physical Measurements on Carcasses

1) Temperature (T₀) of Carcasses

The internal temperature of intact carcasses was taken at loins, thighs and shoulder muscles at a depth of 1 cm immediately after processing (0 hour post-mortem) using a digital probe type thermometer.

2) pH of Carcasses

The pH of the samples was measured using a bench top pH meter with a combined electrode on a mixture of 5 g blended meat and 95 ml distilled water.

2.3. Chemical Analysis of Diet and Muscles

The chemical composition of the experimental diets was analysed for dry matter, crude protein, ash and organic matter using the methods described by the Association of Official Analytical Chemists [12].

The sample muscles were analysed for crude proteins ($N \times 6.25$) according to the AOAC [13] method, while fats content was assessed by the Bourelly method [14].

Lipid oxidation of raw meat was evaluated by measuring the 2-thiobarbituric acid reactive substances (TBARS) based on Genot's method [15] modified by Djenane *et al.* [16], with the resulting colour measured at 532 nm using a spectrophotometer (Unicam UV-visible). A standard curve was elaborated with trichloroacetic acid and thiobarbituric acid. The results were expressed as mg of malondialdehyde (MDA) equivalents per kg of meat.

2.4. Technological Analysis of Muscles

2.4.1. Determination of Water-Holding Capacity

The amount of expressed or "free" water in raw meat was determined in duplicate by the press method described by Tsai and Ockerman [17]. Approximately 0.5 g of the homogenized meat sample was weighed on to Whatman n°4 filter paper and pressed between 2 stainless steel sheets at about 1 kg for 20 min. The amount of water released from the meat samples was indirectly measured by measuring the area of filter paper wetted relative to the area of pressed meat samples. Thus, the water holding capacity was calculated as follows:

$$\text{WHC} = \frac{100 - (A_w - A_m) \times 6.11}{Mc} \times 100$$

where: A_w = Area of water released from meat samples (mm^2);

A_m = Area of meat samples (mm^2);

Mc = Moisture content of meat samples (%);

6.11 = a constant factor.

2.4.2. Napole Technological Yield

The Napole technological yield (NTY) was determined as described by Naveau *et al.* [18] in order to have an idea on the ability of meat to be processed by curing and cooking. One hundred grams of trimmed muscle was cut into cube pieces (1 cm^3) and placed in a beaker. Twenty grams of brine (136 g/L nitrite salt) was added. The cured meat was covered with a 200 g steel weight, kept at 4°C for 24 hrs, cooked for 10 min in boiling water and then dripped for 2.5 hrs. The NTY was calculated as the weight of cured cooked meat (expressed as a percentage of initial meat weight).

$$\text{NTY} = \frac{\text{Dripped weight}}{\text{Meat weight before brining and cooking}} \times 100$$

2.5. Statistical Analysis

Data of the physico-chemical characteristics of the experimental diets and of guinea pigs meat as well as that of

technological characteristics of the guinea pigs meat were presented as means \pm standard deviation. Data were analyzed using the software program Graph Pad Instat. When the Analysis of Variance (ANOVA) showed significant effect on the analyzed parameters, means were separated by the Student-Newman-Keuls test at 5% significance level.

3. Results and Discussion

The chemical composition of the test diets used in this experiment is presented in **Table 2**.

The levels of Dry Matter (DM) and Organic Matter (OM) were not significantly different ($P > 0.05$) in all the experimental diets. The *Pennisetum purpureum* had significantly lower Crude Protein (CP) content than the tests diets. But, no significant crude protein differences were obtained between the tests diets. This could show that, these diets were iso-nitrogenous. However, there were no significant difference in ash contents of the R0 diet and that of *Pennisetum purpureum*. R1, R2 and R3 diets had the highest ash contents ($P < 0.05$) and no significant differences were recorded between these diets.

3.1. Effect of Diet on Growth Performance of Guinea-Pigs

The growth performance of the guinea-pigs fed with diets containing cassava leaf with or without soya bean meal supplementation is presented in **Table 3**.

The female guinea pigs of R2 diet had higher initial weights. But there were no observable differences between females fed with R0, R1 and R3 diets even between females fed with R2, R1 and R0. As for the gender

Table 2. Chemical composition of experimental diets (% DM).

Experimental diets	Chemical composition			
	DM (%)	OM	CP	Ash
R0	90.85 \pm 0.68 ^a	89.52 \pm 1.06 ^a	19.00 \pm 0.87 ^b	10.48 \pm 0.50 ^a
R1	90.38 \pm 0.90 ^a	86.95 \pm 1.69 ^a	18.75 \pm 1.10 ^b	13.05 \pm 0.05 ^{cc}
R2	91.50 \pm 0.53 ^a	87.69 \pm 2.32 ^a	18.81 \pm 1.05 ^b	12.31 \pm 0.52 ^{bc}
R3	90.61 \pm 0.61 ^a	86.46 \pm 1.64 ^a	17.18 \pm 1.73 ^b	13.54 \pm 0.43 ^{dc}
<i>Pennisetum purpureum</i>	90.30 \pm 0.89 ^a	86.32 \pm 1.50 ^a	7.89 \pm 0.10 ^a	9.68 \pm 0.94 ^a

a, b, c, d, e; the means in the same column that have at least one common letter do not have significant difference ($P > 0.05$). **R0**: control diet with 0% of cassava leaf; **R1**: diet with 8% of cassava leaf; **R2**: diet with 10% of cassava leaf; **R3**: diet with 12% of cassava leaf; **DM**: Dry Matter; **OM**: Organic Matter; **CP**: Crude Protein.

Table 3. Growth performance of guinea-pigs according to diet and sex.

Parameters	Sex	Diets			
		R0	R1	R2	R3
Initial weight (g)	♂	91.17 \pm 5.42 ^{ad}	93.00 \pm 13.56 ^{bd}	93.67 \pm 3.72 ^{cd}	78.17 \pm 9.41 ^a
	♀	86.33 \pm 7.50 ^{ad}	82.00 \pm 11.49 ^{ad}	94.50 \pm 9.48 ^{bd}	77.00 \pm 5.73 ^a
Final weight (g)	♂	556.00 \pm 24.83 ^a	559.00 \pm 26.69 ^a	620.83 \pm 42.20 ^b	531.17 \pm 14.41 ^a
	♀	529.17 \pm 19.30 ^a	509.33 \pm 24.40 ^{ab}	529.33 \pm 21.65 ^a	507.33 \pm 25.97 ^a
ADWG (g/d)	♂	3.04 \pm 0.16 ^a	3.03 \pm 0.15 ^a	3.45 \pm 0.28 ^b	2.94 \pm 0.13 ^a
	♀	2.84 \pm 0.14 ^a	2.77 \pm 0.16 ^a	2.89 \pm 0.18 ^a	2.87 \pm 0.16 ^a
Total gain (g)	♂	464.83 \pm 24.35 ^a	466.00 \pm 23.83 ^a	527.17 \pm 42.11 ^b	453.00 \pm 19.48 ^a
	♀	442.83 \pm 11.80 ^a	427.33 \pm 24.34 ^a	434.83 \pm 27.87 ^a	430.33 \pm 25.09 ^a

a, b, c, d; the means in the same row and column that have at least one common letter do not have significant difference ($P > 0.05$). ADWG: Average daily weight gain.

effect, there were no significant differences between males and females. However the males that were fed with R1 (93.00 g) and R2 (93.67 g) diets gave the highest values compared to those fed with R0 (91.17 g) and R3 (78.17 g) diets. Moreover, no significant initial weight differences were obtained between those fed with R0 and R3 diets. Males fed with R0 (556.00 g), R1 (559.00 g), and R3 (531.17 g) diets had no significant differences ($P > 0.05$) in final weight, but there was a significant difference ($P < 0.05$) between them and those fed with R2 (620.83 g) diet. Among females, no significant difference was observed between final weights of those fed with R0, R1, R2 and R3 diets. Similar trends were noticed for average daily weight gain, and total gain. Moreover, the males that were fed with R2 diet gave the highest ($P < 0.05$) average daily weight gain, and total gain compared to those fed with R0, R1 and R3 diets. However no significant difference existed between males fed with R0, R1 and R3 diets for ADWD and total gain. Concerning the sex effect, the initial weight, final weight, average daily weight gain, and total gain were significantly different ($P < 0.05$) between males and females in diet R2, with males recording higher values than females. These results could be attributed to the different anabolic rates between sexes. Males have a higher growth rate and muscle mass, while females present higher fat deposition [19], resulting in higher body weight in males than females in mature animals [20]. In this study, diet R2 with 10% cassava leaf proved to be the best in terms of final weight, average daily weight gain, and total gain. Moreover, differences between these results could be attributed to the proteins quality and digestible nutrients contained in the R2 diet compare to the control diet R0. Then the inclusion of cassava leafs in diets could have resulted in enhance palatability of diets. Nevertheless, the higher values of the final weight, average daily weight gain, and total gain for males as opposed to females suggest that males utilized the diets better than females. In addition, the higher final weight in males may therefore have resulted from an increased breakdown rate and passage of digest products in males more than females.

The initial weight of male and female guinea pigs fed with R2 diet (93.67 and 94.50 g respectively) may be related to higher nutrient density of this diet. These values are clearly higher than those obtained by Niba *et al.* [4] (83.3 g), when they fed guinea pigs with *Desmodium intortum*. These weights are similar to those obtained by Pamo *et al.* [21] (94 g), when guinea pigs were fed with *Moringa oleifera*. Results for the daily weight gain of males R2 for this study are lower than those reported by Pamo *et al.* [21] who obtained 5 g/day with *Moringa oleifera*. These results are higher than the values reported by Manjeli *et al.* [3] for animals under traditional management in 15 weeks (3.30 g/day). The nutritional values of the diets can explain the differences observed in daily weight gain.

3.2. Effect of Diets on Carcass Yield

The carcass yield values of the guinea-pigs are presented in Figure 1.

The eviscerated carcass yield, which was determined after the removal of head, skin and feet ranged between 40.59% and 43.05% for males and between 37.38% and 42.33% for females.

Males fed with diet R2 had the best initial and final weights, while best carcass yield values were obtained with males fed with diet R1. This could be due to the amount of kidney and mesenteric fat issues removed during evisceration. In females, despite the relatively higher initial and final weight of diet R2 than R0, values for carcass yield were lower for R2 than R0. Differences in carcass yields could be due to smaller amount of kidney and mesenteric fat issues removed during evisceration in R2 diet females.

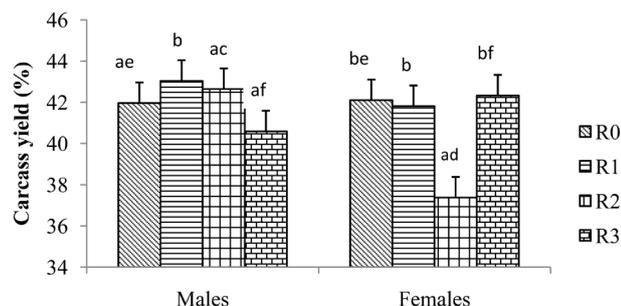


Figure 1. Carcass yield of guinea pigs. The values carrying the same letters do not differ significantly ($P > 0.05$).

With respect to sex, carcass yield of females fed with diet R2 ($37.39\% \pm 1.31\%$) was significantly lower ($P < 0.05$) than that of males ($42.65\% \pm 1.70\%$). This reflects the better performance of males during the experimental period compared to females in terms of carcass yield. These results obtained are higher than those reported by Fotso *et al.* [22] who obtained 35.9% in 15 weeks and 41.9% in 23 weeks under improved management with bran corn and rice based diet. The race of the animals and the diet can explain the observed differences.

3.3. Effect of Diet on Chemical Composition of Some Parts of Guinea-Pig Meat

3.3.1. Lipid Content

The lipid content of the various parts according to diet and sex are presented in **Table 4**.

The lipid content of the various parts varied in the males between 5.26% and 10.15% and in the females between 6.24% and 15.95%. At the level of the loin, no significant difference was observed ($P > 0.05$) between the lipid content of both males and females having received diets R0, R1, R2 and R3. The lipid content of the thighs of the males who received diets R3 (5.26%) were significantly different ($P < 0.05$) from those that received diets R1 (8.94%) and R2 (8.45%). Those that received diets R1 and R2 had higher values while the lower values were for those who received diets R0 and R3. However, females fed with diets R0 and R3 had highest values in the thighs, 9.04 and 10.53% respectively compared to those fed with diets R1 (6.24%) and R2 (7.85%). Similar trends were noticed in shoulders of females and males, where males having received R1 (12.73%) and R2 (12.30%) were significantly higher ($P < 0.05$) than those of diet R3 (8.82%), while females receiving R0 (13.77%) and R3 (15.95%) diets were significantly higher than those of diet R1 (10.47%).

Higher lipid levels found in thighs, shoulders and loins of males receiving R1 and R2 diets, and females fed with R0 and R3 diets may suggest a higher probability of occurring oxidative processes in the muscles of those animals.

As for the sex effect, the lipid content of the females receiving diets R0 and R3 at the level of the shoulders and R3 at the level of the thighs were significantly higher ($P < 0.05$) than those of the males. But, these values at the level of the loin were similar for both sexes ($P > 0.05$).

The higher values in females could be explained by the implication of hormones. Indeed, oestrogens stimulate the distribution of lubricating mass at the level of the basin and thighs [23]. However, the low lipid content in the males is due to the presence of testosterone, as the presence of testicular hormones are related to greater muscle growth capacity in bulls [24]. The observed sex effect is in agreement with the results of Horcada *et al.* [25] who, by using the *Longissimusdorsi* of male and female lamb found that, the contents in intramuscular fat were higher in females (2.74% - 3.54%) than in males (1.87% - 3.15%). These results corroborate those found by other authors [26] who showed that the lipid content vary according to their anatomical position. These results were also higher than those of Minvielle *et al.* [27], who showed that, lipid content in the *Biceps femoris* and *Semimembranosus* muscles of the thigh of pig, was 4.18 % and 2.20 % respectively. Moreover, Nold *et al.* [28] showed that the lipid content of fourteen muscles of the pig meat within the same carcass varied significantly. Furthermore, the fat content of guinea pigs meat observed in this study was higher compared to that of Ruiz *et al.* [29] who obtained 1.23% for Nelore-cross bull long is simusmuscle (LM), and Nelore-cross steer LM fat content was 2.17%.

Table 4. Effect of diet on lipid content of some parts of guinea-pig meat (% of fresh matter).

		Diets				
	Parts	Sex	R0	R1	R2	R3
Lipid content %	Loin	♂	6.83 ± 0.10 ^a	7.78 ± 1.28 ^a	7.25 ± 0.39 ^a	6.13 ± 0.04 ^a
		♀	7.70 ± 1.13 ^a	6.45 ± 2.24 ^a	6.46 ± 1.67 ^a	8.90 ± 0.04 ^a
	Thigh	♂	7.30 ± 0.33 ^{ad}	8.94 ± 0.24 ^{bd}	8.45 ± 0.67 ^{cd}	5.26 ± 0.28 ^a
		♀	9.04 ± 1.00 ^{ad}	6.24 ± 0.05 ^{ad}	7.85 ± 1.86 ^{ad}	10.52 ± 0.61 ^b
	Shoulder	♂	10.15 ± 0.45 ^{ad}	12.73 ± 0.31 ^{bd}	12.30 ± 0.50 ^{ad}	8.82 ± 0.30 ^a
		♀	13.77 ± 0.55 ^{ce}	10.47 ± 0.77 ^a	13.50 ± 1.92 ^{de}	15.95 ± 0.99 ^{be}

a, b, c, d, e: means of the same affected line of the same letter are not significantly different in $P > 0.0$. A, B: means carrying the same letters in the same column are not statistically different ($P > 0.05$).

3.3.2. Protein Content

The protein content of the various parts according to the diets and sex expressed as wet weight basis are presented in **Table 5**.

This table shows that, the protein content in males ranged between 13.64% and 21.68% while in females it ranged between 13.58% and 22.89%. These contents at the level of the loin of males and the thigh of females guinea-pigs having received diets R1 (19.44% and 20.09%), R2 (20.23% and 18.11%) and R3 (20.51% and 17.17%) were similar to those of the guinea-pigs who received diet R0 (20.28% and 18.04%). At the level of the female loins, the protein content of those on diets R1 (22.89%) and R2 (22.74%) was significantly higher compared to the control R0 (17.20%) and R3 (16.19%). However the males receiving diet R1 (17.68%) had protein content similar to that of the control. As for the shoulder, in males, a significant fall in protein content was noted with diets R1 (13.91%) and R2 (13.64%) compared with R0 (18.60%) and R3 (21.09%). It is however important to mention that, a significant difference was observed between the protein content of R0, R3, R1 and R2 for this part. The protein content at the level of the shoulders of females receiving diets R2 (16.55%) and R3 (13.58%) remained comparable to those of the control R0 (15.29%), while those of the female receiving diet R1 (22.43%) were significantly higher ($P < 0.05$) compared to the control. As for the sex effect, the protein content of males receiving all diets at the level of shoulders and R3 at the level of thighs and loins were significantly higher than those of females ($P < 0.05$).

The raised contents obtained at the level of the loin, were in line with those found by Niba *et al.* [4], who showed that the protein content of the adult meat of guinea-pig of English race oscillates between 20% and 21%. The low contents recorded in this study were in agreement with those found by Rinaldo and Mourot [30], in the muscle *Semispinalis* (18.2%).

3.3.3. Lipid Oxidation

The oxidation of lipids is one of the most important changes during food storage and processing. It depends on the polyunsaturated fatty acids (PUFA) content, as well as on the balance between anti- and pro-oxidant compounds [31]. The determination of thiobarbituric acid reactive substances (TBARS) is widely used as an index of lipid oxidation. The results of TBARS in males and females are shown in **Figure 2** and **Figure 3** respectively.

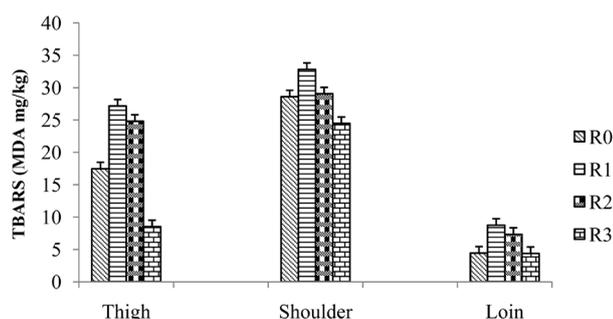


Figure 2. TBARS values of the various parts analysed in the males (MDA mg/Kg of fresh tissue).

Table 5. Effect of the various diets on the protein content (% of fresh matter) of some parts of the meat of guinea-pig.

	Parts	Sex	Diets			
			R0	R1	R2	R3
Protein content (%)	Loin	♂	20.28 ± 0.72 ^a	19.44 ± 0.55 ^{ad}	20.23 ± 1.01 ^{ad}	20.51 ± 1.50 ^{ad}
		♀	17.20 ± 0.99 ^a	22.89 ± 0.67 ^{bd}	22.74 ± 0.37 ^{cd}	16.19 ± 1.35 ^{af}
	Thigh	♂	18.74 ± 0.89 ^{ce}	17.68 ± 0.93 ^{de}	15.34 ± 0.09 ^{ac}	21.68 ± 1.10 ^b
		♀	18.04 ± 1.43 ^{ac}	20.09 ± 0.14 ^{ac}	18.11 ± 0.51 ^a	17.17 ± 0.66 ^a
	Shoulder	♂	18.60 ± 0.41 ^c	13.91 ± 0.93 ^a	13.64 ± 0.23 ^a	21.09 ± 0.60 ^b
		♀	15.29 ± 0.71 ^a	22.43 ± 1.31 ^b	16.55 ± 0.48 ^c	13.58 ± 0.79 ^a

a, b, c, d, e, f: means of the same affected line and column of the same letter are not significantly different in $P > 0.05$.

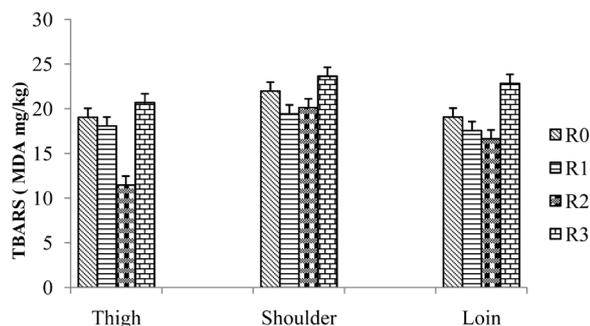


Figure 3. TBARS values of the various parts analysed in the females (MDA mg/Kg of fresh tissue).

These TBARS values in males (**Figure 2**) varied from 4.39 to 32.81 mg/kg. The highest TBARS values were obtained at the level of the shoulders, followed by the thighs and finally the loin. This implies that in males, membrane lipids would oxidize faster at the level of the shoulders and thighs, compared to the loin. This can be due to the type of lipid found at that different parts [30]. At the level of the shoulders, TBARS values for males receiving diets R1 (32.81 mg/kg), R2 (29.05 mg/kg) and R3 (24.48 mg/kg) did not differ from those of males receiving diet R0 (28.59 mg/kg): implying that the experimental diets as well as the control had the same effect on lipid oxidation at this level. At the level of the thighs, only diet R3 (8.52 mg/kg) significantly limited lipid oxidation even more than the control, but there were no significant differences between males fed with R2 and R1 diets. At the level of the loin, there were no significant differences between males fed with all diets. These results suggest that the oxidative effect of the diet depends on the origin of the muscle. However, a lower oxidation in muscles expressed as TBARS values suggests a positive effect of cassava leaf, especially for guinea-pigs that received R3 diet.

In females, these values ranged between 11.46 and 23.64 mg/kg. At the level of the thigh the lowest ($P < 0.05$) TBARS values were obtained for females fed with R2 and the effect of R0; R1 and R3 were not significantly different. However these values at the level of the shoulders were statistically comparable to those of the control (R0). But at the level of the loins, there were observable differences between females fed with R3 and R0, R1 and R2 diets. The quality and quantity of fat produced by the different diets at different levels could explain the differences observed. Indeed there exist a perfect and positive correlation ($r = 0.69$) between the lipid contents and their oxidation rates.

TBARS values obtained in this study were very high, ranging from 4.39 to 32.81 mg MDA/kg meat in males and from 11.46 and 23.64 mg MDA/kg meat in females; these are greatly above 1 mg/kg meat, the threshold for off-flavour development [32]. The results presented here showed that the experimental diets used induce important oxidative changes and it can be suggested that these diets could contain pro-oxidant compounds (free iron for example).

3.4. Effect of Diet on Some Technological Parameters of the Meat of Guinea-Pig

3.4.1. Temperature

The effect of diet on the temperature of the thighs, loins and shoulders of guinea-pigs' carcasses is presented in **Table 6**.

The temperature values after slaughter ranged between 30.80°C and 32.87°C. The various diets used did not have any influence on the temperature values independent of the gender of guinea pigs at the level of the loins and shoulders. This would mean that these formulations composed of cassava leaves did not affect the temperature of guinea-pigs' carcasses at the level of loin and shoulder. The males fed with diets R2 and R3 gave the highest temperature values at the level of the thighs compared to those fed with diets R0 and R1. But there existed significant differences between thighs of males fed with diets R0, R1, R2 and R3. For females, those that were fed diet R0 gave the highest temperature values compared to those fed with experimental diets.

3.4.2. pH

The results of pH post-mortem attributes are shown in **Table 7** for the various muscles (loin, thigh and shoulder muscles).

Table 6. Effect of the various diets on temperature of some parts of the meat of guinea-pig.

		Diets				
Parts	Sex	R0	R1	R2	R3	
Temperature (°C)	Loin	♂	31.48 ± 0.92 ^a	32.34 ± 1.20 ^a	32.18 ± 0.97 ^a	32.27 ± 0.85 ^a
		♀	31.96 ± 0.88 ^a	31.81 ± 0.91 ^a	31.93 ± 1.32 ^a	32.18 ± 0.97 ^a
	Thigh	♂	31.16 ± 1.31 ^a	32.21 ± 0.01 ^{bc}	32.87 ± 0.09 ^{cd}	32.87 ± 0.09 ^{de}
		♀	31.72 ± 0.45 ^a	30.80 ± 0.64 ^a	31.68 ± 0.09 ^{bd}	31.68 ± 0.09 ^{cd}
	Shoulder	♂	31.44 ± 1.05 ^a	32.38 ± 0.28 ^a	31.25 ± 0.73 ^a	31.25 ± 0.73 ^a
		♀	31.13 ± 0.73 ^a	31.80 ± 0.40 ^a	31.72 ± 0.44 ^a	31.72 ± 0.45 ^a

a, b, c, d, e, means of the same affected line and column of the same letter are not significantly different at $P > 0.05$.

Table 7. Effect of the various diets on pH of some parts of the meat of guinea-pig.

		Diets				
Parts	Sex	R0	R1	R2	R3	
pH	Loin	♂	6.12 ± 0.01 ^a	5.99 ± 0.14 ^a	6.04 ± 0.09 ^a	5.98 ± 0.12 ^a
		♀	6.10 ± 0.02 ^a	5.98 ± 0.12 ^a	6.12 ± 0.02 ^a	6.04 ± 0.01 ^a
	Thigh	♂	6.09 ± 0.00 ^a	5.98 ± 0.09 ^a	6.11 ± 0.01 ^a	6.03 ± 0.03 ^a
		♀	6.08 ± 0.03 ^a	5.99 ± 0.06 ^a	6.08 ± 0.06 ^a	6.03 ± 0.03 ^a
	Shoulder	♂	6.15 ± 0.01 ^a	6.06 ± 0.06 ^a	6.11 ± 0.08 ^a	5.99 ± 0.01 ^a
		♀	6.12 ± 0.01 ^a	5.99 ± 0.11 ^a	6.13 ± 0.02 ^a	6.05 ± 0.06 ^a

The pH values after slaughter which ranged between 5.98 and 6.15 were in agreement with those found by other authors [33]. The various diets used did not have any influence on the pH values and on the gender of guinea pigs. These results were in accordance with the observations made by Kirton *et al.* [34] on lambs as well as those found by Diaz *et al.* [35] who did not observe any difference in pH with respect to the sex of lambs. The pH values of this study show that, guinea pigs in this context have not been stressed before slaughtering, which could explain the non difference in pH values. The results obtained corroborate those of Lefaucheur *et al.* [36] who did not observed any difference in pH 45 min after slaughter in the *Longissimus* and *Semispinalis* muscles of the pig.

3.4.3. Water-Holding Capacity

It arises from **Table 8** that, the effect of diet R2 on water holding capacity is not significantly different ($P > 0.05$) from that of R0 at the level of the loin and thigh for both males and females and at the level of shoulder for males. However, diet R1 independent of the sex significantly lowered ($P < 0.05$) the water holding capacity at all level of guinea-pig meat compared to the control. At the shoulder level, the water holding capacity obtained with diet R3 for males (73.38%) was not significantly different ($P > 0.05$) with that of control R0 (71.93%). At the other level of guinea-pig meat independently of the sex, this diet significantly lowered ($P < 0.05$) the water holding capacity compared to the control.

In females, the highest values for water holding capacity were found at the level of the shoulders in the control R0 (74.76%), compared to females fed with R1 (65.85%), R2 (69.85%) and R3 (67.47%). Significant water holding capacity differences were observable between females fed with R0 and those fed with R1, R2 and R3. With respect to gender, females fed with diets R0, R2 and R3 at the level of the loin recorded poor water holding capacity compared to males. The values obtained for females fed with R1, R2 and R3 diets at the level of the thighs and the shoulders were significantly high ($P < 0.05$) compared to males.

The water holding capacity of some parts of the meat of guinea-pig showed that muscle from guinea-pigs fed with R0 and R2 diets held more water than those fed with R1 and R3 diets. These results showed that muscles of

guinea-pigs fed with R0 and R2 diets could be able to hold on to inherent water because no heat of any sort was applied that could have denatured the proteins to cause any considerable lowering of water holding capacity. In addition, water holding capacity is the ability of muscle or meat to retain its naturally occurring water during application of any external force such as cutting, grinding or processing [37]. Water holding capacity of meat is greatly influenced by solubility and state of its myofibrillar and sarcoplasmic protein.

The difference observed in this study was similar to that of Diaz *et al.* [38]. However Bouton *et al.* [37] showed that the water holding capacity increases according to an increase in pH. Indeed, the absence of difference in pH noted in this study makes us believe that it has little impact on this difference.

3.4.4. Napole Technological Yield (NTY)

It is clear from Table 9 that only R1 (55.70%) and R3 (46.00%) respectively for males and females reduced significantly ($P < 0.05$) the NTY at the level of the loin, compared to the control. At the level of the thigh, the highest NTY was obtained with males fed with R2 (89.60%), while those fed with R1 (55.80) and R3 (75.00%) were significantly ($P < 0.05$) lower compared to the control (85.30%). In females, all cassava leaves based diets significantly lowered the NTY compared to the control. For the shoulders, the NTY of male guinea pigs fed with R0 (95.50%) and R2 (96.40%) were significantly higher ($P > 0.05$), while those fed with R1 (58.50%) and R3 (72.70%) remained low. As previously observed with the thighs, the NTY at the level of the shoulders of females fed with R1 (68.60%), R2 (68.60%) and R3 (66.60%) remained significantly lower ($P < 0.05$) as compared to the control (90.60%).

With respect to the sexes, the NTY values of females fed with R3 at the level of the loin, R2 and R3 at the level of the thighs and shoulders were significantly lower ($P < 0.05$) than those of males. In terms of the R1 diet, the lowest NTY was obtained in males at the level of the loins and shoulders.

In general, the diet containing only soya bean meal (R0) did not significantly affect the NTY with respect to the sex of guinea pigs. Literature reports that, low NTY may be explained by a combination of poor weight gain during brining and larger cooking losses, which would indicate a change in the function of proteins [39].

Table 8. Effect of the various diets on water-holding capacity of some parts of the meat of guinea-pig meat.

		Diets				
	Parts	Sex	R0	R1	R2	R3
Water-holding capacity (%)	Loin	♂	80.70 ± 0.94 ^{cd}	53.34 ± 1.17 ^{af}	81.21 ± 1.86 ^{bd}	51.93 ± 0.39 ^{ag}
		♀	71.81 ± 2.92 ^{de}	52.22 ± 0.39 ^{bf}	69.46 ± 1.94 ^{ce}	16.37 ± 0.47 ^{ah}
	Thigh	♂	44.38 ± 0.00 ^{ce}	35.20 ± 0.28 ^b	47.08 ± 4.99 ^{de}	13.99 ± 2.88 ^a
		♀	47.90 ± 4.03 ^{ce}	13.91 ± 0.00 ^a	52.04 ± 0.92 ^{de}	38.13 ± 0.00 ^b
	Shoulder	♂	71.93 ± 2.48 ^{bef}	45.16 ± 0.00 ^{ag}	74.35 ± 0.39 ^{dei}	73.38 ± 1.03 ^{cej}
		♀	74.76 ± 0.38 ^{df}	65.85 ± 1.04 ^{ah}	69.85 ± 0.46 ^{cej}	67.47 ± 2.07 ^{ael}

a, b, c, d, e, f, g, h, i, j: means of the same affected line and column of the same letter are not significantly different at $P > 0.05$.

Table 9. Effect of the various diets on Napole technological yield of some parts of guinea-pig meat.

		Diets				
	Parts	Sex	R0	R1	R2	R3
Napole Technological Yield (%)	Loin	♂	82.00 ± 1.41 ^{cef}	55.70 ± 4.10 ^a	84.90 ± 3.81 ^{dfg}	67.80 ± 2.83 ^{be}
		♀	79.40 ± 0.57 ^{cef}	69.00 ± 3.96 ^{be}	80.80 ± 9.90 ^{deg}	46.00 ± 1.13 ^a
	Thigh	♂	85.30 ± 4.67 ^{ce}	55.80 ± 1.41 ^a	89.60 ± 9.33 ^{de}	75.00 ± 2.83 ^{be}
		♀	80.80 ± 2.26 ^{be}	64.50 ± 0.42 ^a	68.80 ± 3.96 ^a	58.20 ± 0.00 ^a
	Shoulder	♂	95.50 ± 2.69 ^{ce}	58.50 ± 3.25 ^{af}	96.40 ± 1.98 ^{de}	72.70 ± 2.69 ^{bh}
		♀	90.60 ± 4.53 ^{be}	68.60 ± 0.38 ^{ag}	77.30 ± 4.67 ^c	66.60 ± 0.57 ^{ah}

a, b, c, d, e, f, g, h: means of the same affected line and column of the same letter are not significantly different in $P > 0.05$.

4. Conclusions

The results of this study reveal that the diet containing 10% cassava leaf (R2) was considered as the optimum cassava-leaf level to achieve optimum growth and to produce good quality meat, compared with other meat such as rabbit and pork.

Chemical composition analyses of guinea-pig meat varied per the anatomical origin and the gender of the animals. The females fed with R2 and R3 had lipid content higher than the males at the level of the thighs and shoulders while no difference ($P > 0.05$) was noted at the level of the loin. Cassava leaf significantly affected protein content not only with respect to the anatomical origin, but also with respect to sex. The evaluation of the secondary products of oxidation showed that, the shoulders lend themselves more quickly to lipid oxidation than the thighs and the loins, whatever be the gender or the diet. Moreover, it was noted that lipid oxidation was limited at the level of the thighs of males fed with R2 and at the level of the loins and thighs with females fed with R3, suggesting that these diets were less oxidizing. From the technological point of view, the study did not show any significant difference between the pH post-mortem values, with respect to the anatomical origin and the gender of the animals. Indeed, the presence of 10% cassava leaf in the diet of guinea-pigs significantly increased the values of the water holding capacity and the technological yield.

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