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Influences of Pelled Feeds Formulated with Vegetables, Household and Industrial Residues on the Performance of Rabbits *(Oryctolagus cuniculus)*

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Abstract **Original Research Article**

In Côte d'Ivoire, the challenges facing rabbit breeders are essentially food-related. The aim of this study is also to produce low-cost mixed foods based on residues that can feed rabbits in the same way as those sold on the market. To do this, plants, agricultural and industrial residues were collected, treated, and powdered. Dietary supplements (F1, F2, F3, and F4) are formulated and granulated. They were tested on 5 lots of 10 rabbits each, in comparison to a commercial food. Physicochemical characteristics of diet, zootechnical parameters, mortality and morbidity rates of the animals were determined. The biochemical parameters and the organoleptic quality of the meat were determined. The dry matter contents of the diets range from 82 3.10% for diet F3 to 89.2 1.95% for diet F2. All results are significantly different at P<0.05. The mean protein content ranged from 20.47 ±2.52 to 23.27 ±1.56% DM for F1 and F2 respectively. The crude fiber contents vary from 16.23 ±2.50 to 26.71 ±5.73% DM for F1 and F4 respectively. The carbohydrate contents varied from 15.03 ± 1.25% DM (for F3) to 21.6 ±1.80% DM (for F2). The cost of feeding a rabbit for 56 days on the F2 diet was 724 FCFA, which was the least expensive, followed by the F1 diet (744 FCFA) and the F3 diet (845 FCFA). Of the experimental diets formulated, diet F4 was obviously the most expensive (1163 FCFA). However, its price was lower than the amount paid for the control diet (1628 FCFA). For the carcass, there were no significant differences in the values obtained for weight and yield at P > 0.05. The average scores obtained for odor were 3.42 ± 0.93, for taste, 3.45 ± 1.10 and for tenderness, 3.48 ± 1.07. The overall scores for F1, F2 and F4 were statistically identical and significantly higher than F3 and the control. Cholesterol, creatinine, and urea levels were within the range of the standard, whereas triglyceride levels were above the standard.

Keywords: Rabbit, residues, feeding, zootechnical parameters, control diet, performance.

INTRODUCTION

By 2040, the population of Côte d'Ivoire will have exceeded 50 million. Ivorian agriculture will have to be able to cope with this population growth and feed the entire population. New innovative, sustainable and socially responsible production methods must be adopted. With regard to animal production, the country must no longer be satisfied with privileging only the so-called conventional sectors, which, despite all the efforts made, keep Côte d'Ivoire dependent on the outside for meat products. It is necessary to bet and give breeding a chance because cuniculture is, incorrectly judged not conventional but very prolific, requiring very little space, very little financial means, and adapting very well everywhere.

However, there is a major challenge in raising rabbits in Côte d'Ivoire: that of feeding them. Indeed, the quality of pellets, their availability, and their high cost on the market are all difficulties that farmers must overcome on a daily basis (Bouatene, 2013). Supply disruptions coupled with stocks of pelleted feed that are sometimes unsuitable or delivered defective are regular situations that cause digestive disorders, weight loss, altered caecal microbial activity, altered digestive motricity, and even death of the rabbits (Gidenne, 2005). The survey by Djama *et al.*, (2020) revealed that many farmers have abandoned their rabbit farming activities and others have suffered numerous animal losses as a result of consuming defective feed deliveries. Add to this, the high cost of these pelleted feeds that farmers imperatively depend on to feed their animals regularly. All these problems contribute to the unavailability and inaccessibility of rabbit meat in Côte d'Ivoire. The production of a quality feed at a lower cost would be a better way to make rabbit farming profitable.

The rabbit, which feeds well on agricultural waste, could easily find its source of food in a country like Côte d'Ivoire, which has an agricultural vocation. A good combination of household waste from agricultural and/or industrial activity could constitute a food resource of choice to be valorized in rabbit breeding. Indeed, Tchibozo *et al.*, (2017) showed that their use would significantly reduce the cost of purchasing complete rabbit feed.

The objective of this study is therefore to propose to the Ivorian rabbit farming new formulas of available and accessible mixed feed.

MATERIALS AND METHODS

Experimental site

The experimentation took place in the commune of Bingerville in Côte d'Ivoire, whose geographical coordinates are 5° 21' 708" North latitude and 3° 54' 639" West longitude. Throughout the trial, the average temperature at this location fluctuated between 26 and 28 °C during the period.

Collection of agricultural residues and by-products

The agricultural residues and by-products used in this study were collected at different locations. Soybean, copra and cotton cakes, cashew nuts, wheat bran and fish meal were obtained from a feed mill in the commune of Yopougon (Abidjan). Cassava peelings were collected from female attiéké producers in the commune of Cocody (Abidjan) and grasses (fodder) were collected from the Université Félix Houphouët-Boigny. Rice and corn bran were collected in the town of Akoupé. Brewers' grains were obtained from the Solibra factory in Abidjan.

Treatment of the collected residues

The treatment of the collected residues consisted of sorting the cassava peels and gaminis in order to eliminate impurities. The residues were then washed and sun-dried on black tarpaulins to reduce moisture content under 16% as recommended by Chene (2001). The different inputs were then individually ground using an electric hand grinder. The resulting powder was stored in very clean plastic bags.

Formulation of experimental diets

The formulation of the experimental diets was carried out taking into account the nutritional requirements of rabbits as recommended by Lebas (2004). Thus, four diets represented in Table 1 were theoretically formulated according to the nutritional requirements of rabbits using the trial and error method of Afolayan and Afolayan (2008). For each diet, the inputs were weighed according their quantity to be incorporated, put together and then mixed by hand for 15 min to obtain a homogeneous mixture. Table 1 show only the quantity of residues which were mixed.

Table 1: Model for the formulation of agricultural residue pellets

Diets				
Inputs (g)	**F1**	**F2**	**F3**	**F4**
Rice bran	20	20	20	
Corn bran	10	10	20	15
Wheat bran				15
Soybean meal	20		10	
Cottonseed meal		20	10	10
Fish meal		20	10	10
Copra cake				25
Cashew residue				25

NB: the other ingredients were put to complete each diet at 100 g

Management of young rabbits and conduct of the experiment

The experiment was conducted under real farm conditions (cages arranged in the open air benefiting from shade and fresh air) as practiced by the majority of farmers according to Djama *et al*., (2020). Thus, 50 rabbits of *Oryctolagus cuniculis* strain aged between 4 and 6 weeks and having an average weight of 550 ±10 g were individually arranged in cages in a random manner without taking into account the sex. To do this, five batches of 10 rabbits each were formed. One batch was fed with the control diet and 4 batches were fed with a specific type of diet formulated (F1, F2, F3 and F4).

The nutritional study was conducted according to the method described by De Blas and Wiseman, (1998). The study lasted for 63 days including 7 days adaptation phase during which all the rabbits were fed with the control diet (FACI). For feed distribution, each young rabbit received 50 g of feed in pellet form each morning between 9:00 and 10:00 am. The amount of feed, served at satiation, increased during the experiment until it reached 100 g depending on the consumption rate of each animal. Water was served ad libitum. The next day, food scraps or refusals were collected and weighed before any further distribution.

A prophylactic treatment with sulfadimidine, pyrimethamine, tetracycline, vitamin A, K3 and B2 was administered to avoid stress and prevent diarrhea due to coccidiosis over three days.

The zootechnical parameters evaluated were feed intake (FIC) (Combes and Dalle, 2005), average feed consumption (AFC) (Djago and Kpodekon 2000); average daily weight gain (ADWG) (Lebas *et al*., 1996); body dimensions (Ogbuewu *et al*., 2010) and feed conversion ratio (FC) (Lebas *et al*., 1996). Mortality and morbidity rates were determined according to Lebas (2007) and the Health Risk Index (HRI) according to Gidenne *et al*., (2010).

Blood samples were collected according to the method described by Weiss *et al*., (2000) and the determination of biochemical blood parameters (total cholesterol, creatinine, glycemia, phosphorus, triglycerides and urea) was performed using a multiparametric automaton.

Physicochemical analysis of feed and feces

Dry matter and ash contents were determined according to the methods described by AOAC (1990) using an oven and a muffle furnace respectively. Protein content was determined according to the Kjeldahl method as described by AOAC (1990) by successively mineralizing, distilling and titrating plant and fecal matrices. Lipid and fiber contents were determined using the method described by AFNOR (1986). The carbohydrate content was calculated by deduction from the FAO (2002) mathematical formula.

Evaluation of the cost of the formulas

The cost price (expressed in CFA Francs) of one (1) kg of each diet was determined from the purchase price of the raw materials, the price of technological treatments (grinding, granulation) and the transport costs of the residues. For the FACI control diet, the cost was based on the market price of a 25 kg bag, which is 6000 CFA francs.

Evaluation of the meat and organoleptic characteristics of the rabbit meat

Three animals per batch were slaughtered according to the method of Fielding (1993). For organoleptic characteristics, the slaughtered animals were cooked over a fire of embers. A panel of 32 people aged 18 years and older, of all sexes, was formed. Pieces of cooked meat from each batch of rabbit were offered to the panelists. At the end of the tasting, each taster gave their opinion on the overall appreciation of the braised meats according to whether they disliked, liked a little, liked or liked a lot according to a rating scale (1 to 4).

Statistical Analysis

All trials were conducted with three replicates and the results expressed as mean ± standard deviation. Statistical analyses were performed using Statistica ANOVA version 10.0 software. Test significance was determined by comparing the probability P associated with the Duncan test statistic at the 5% threshold (Kahnn, 1985).

RESULTS

Physicochemical composition of the granule formulated from agricultural residues

The macronutrient composition of the granule formulated from agricultural residues is given in Table 2. The dry matter contents range from 82 ± 3.10% for diet F3 to 89.2 ± 1.95% for diet F2, respectively. The values for F1, F2 and F3 are statistically equal and significantly different at $P<0.05$ from that of F4 and the control (84 ± 1.56%), which is lower than F1, F2 and F3. The mean protein contents ranged from 20.47 ± 2.52 to 23.27 ± 1.56% DM for F1 and F2 respectively. The protein contents of our diets were statistically equal but different ($P < 0.05$) from those of the control which was lower (16.6 ± 1.46% DM). Regarding the percentage of crude fiber in the formulas, the contents vary from 16.23 ± 2.50 to 26.71 ± 5.73 % DM for F1 and F4 respectively. The contents of F1, F2 and F3 are significantly equal and different at the 5% threshold from that of F4 which is higher. The control value is the lowest. The carbohydrate contents varied from 15.03 ± 1.25% DM (for F3) to 21.6 ± 1.80% DM (for F2). These contents were statistically different from each other two by two at $P < 0.05$. Diets F2 and F1 had the highest carbohydrate contents 21.10 ± 2.85% DM. The lipid contents of the diets ranged from 4.21 ± 1.73 to 16.24 ± 1.44% DM for diets F1 and F4 respectively. All the values obtained were significantly different ($P < 0.05$) from each other and the F4 diet had the highest value with 16.24 ± 1.44% DM while the control diet contained five times less lipid (3.00 ± 0.98% DM) than the F4 diet. As for the ash contents of the diets, the contents obtained varied from 3.30 ± 0.75 to 7.70 ± 0.23 % DM for F1 and F2 respectively. These contents are statistically different two by two and are all significantly different from the control which is the highest (9.4 ±1.80 DM). It was also observed a significant difference ($P < 0.05$) at the level of the means.

Table 2: Macronutrient composition of granules formulated from agricultural residues

Diets							
Macronutrients (%)	F1	F2	F3	F4	**Control diet**	Cv (%)	P>F
Dry mater	88.62 ± 2.80[a]	89.2 ± 1.95[a]	87.65 ± 2.56[a]	82±3.10[b]	84±1.56[b]	2.45	0.00
Proteins	20.47 ±2.52[a]	23.27± 1.56[a]	22.35 ± 1.81[a]	21.63 ± 1.5[a]	16.6 ± 1.46 [b]	3.90	0.02
Fibers	16.23 ±2.50[bc]	18.55 ± 2.24[b]	17.48 ± 3.72[b]	26.71 ± 5.73[a]	13.2 ± 1.90 [c]	1.45	0.00
Carbohydrates	20.60 ± 3.90[a]	21.6 ± 1.80[a]	15.03 ± 1.25[b]	17.87 ± 0.23[b]	16.76 ± 0.54 [b]	9.34	0.00
Fat	4.21 ± 1.73[c]	6.00 ± 1.66[b]	5.20 ± 0.31[bc]	16.24 ± 1.44[a]	3.00 ± 0.98 [d]	2.34	0.01
Ash	3.30 ± 0.75[d]	7.7 ± 0.23[b]	5.08 ± 0.42[c]	4.73 ± 1.20[c]	9.4 ±1.80 [a]	2.9	0.001

Values followed by standard deviations represent means obtained after three replicates. For each row of the table, values that are not assigned the same letter are significantly different at P < 0.05.

Zootechnical influence of granules formulated from agricultural residues on the body length of rabbits

Figure 1 shows the result of the variation in body length of rabbits fed with granules formulated from agricultural residues during 56 days of experimentation. The length of the rabbits varied from 18.8 ±5.50 cm to 22.70 ±5.16 cm respectively for the rabbits fed with diet F1 and diet F3. The values obtained at the end of experimentation showed significant differences (P < 0.05 with the greatest variation in body length obtained in rabbits fed the control diet (24.7 ± 4.1 cm).

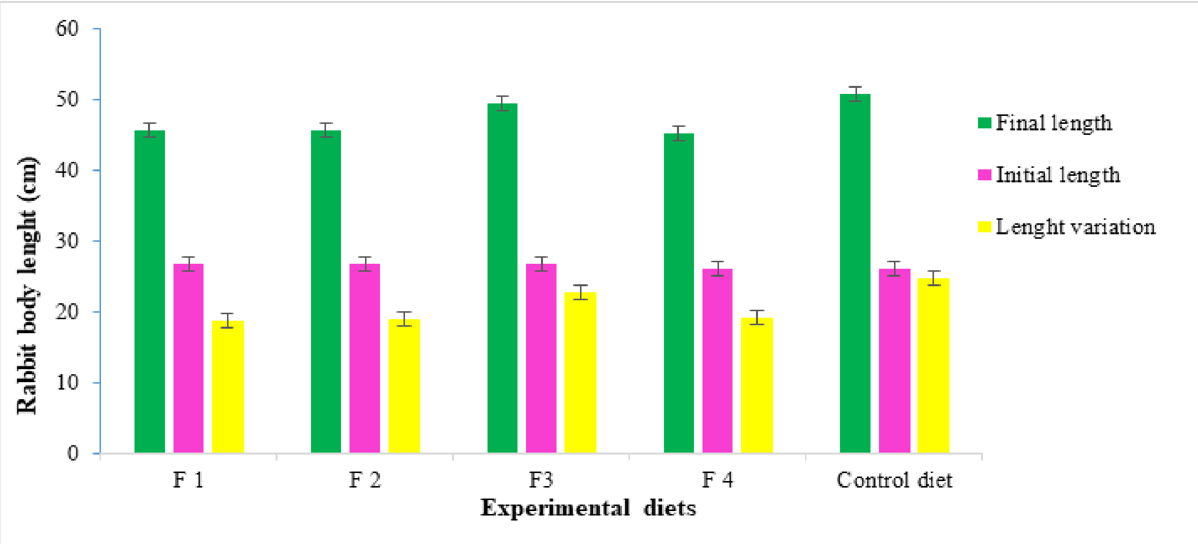

Figure 1: Variation in body length of rabbits during the 8 weeks of experimentation

Weight gain, food intake and consumption index

The average daily weight gains (ADG) of the animals calculated per 14-day interval are recorded in Table 3 below. The values obtained range from 20.73 ± 3.80 to 25.32 ± 4.32 g/d for diets F2 and F3, respectively. The values for diets F3 (25.32 ±4.32 g/d), F4 (23.01 ±3.6 g/d), and the control (24.14 ± 2.35 g/d) were not statistically different but were significantly different from the values for diets F1 (22.40 ±1.60 g/d) and F2 at P < 0.05. Diet F2 recorded the lowest value. For the consumption indices, the values ranged from 2.58 ± 0.13 and 3.55 ± 0.32 for the F4 and F1 diets, respectively. The values obtained for the diets are significantly identical to that of the control (3.42 ± 0.40) at the 5% threshold.

Table 3: Weight gain, food intake and consumption index of rabbit fed with granules formulated from agricultural residues

Diets					
Parameters	**F1**	**F2**	**F3**	**F4**	**Control**
ADG(g/d)	22.40 ±1.60[b]	20.73 ±3.80[c]	25.32 ±4.32[a]	23.01 ±3.6[a]	24.14±2.35[a]
Food intake	83.45±4.76[ab]	77.93±8.04[b]	83.10± 6.38[ab]	67.48±7.66[c]	87.39±5.77[a]
Consumption indice	3.55 ± 0.32[b]	3.44 ± 0.12[b]	2.84 ± 0.21[a]	2.58 ± 0.13[a]	3.42 ± 0.40[a]

Values followed by standard deviations represent means obtained after three replicates. For each row of the table, values that are not assigned the same letter are significantly different at P < 0.05. ADG : average daily weight gains

Weight change

During the 56 days of experimentation, all formulated diets promoted weight growth of the animals as shown in Figure 2. However, the weights of rabbits fed the F3 and Control diets remained the highest (P < 0.05) with weights of 1982 ± 78.54g on day 91. Animals fed the F2 diet had the lowest weight gains (1759.41 ± 48.37g) at the end of the experiment.

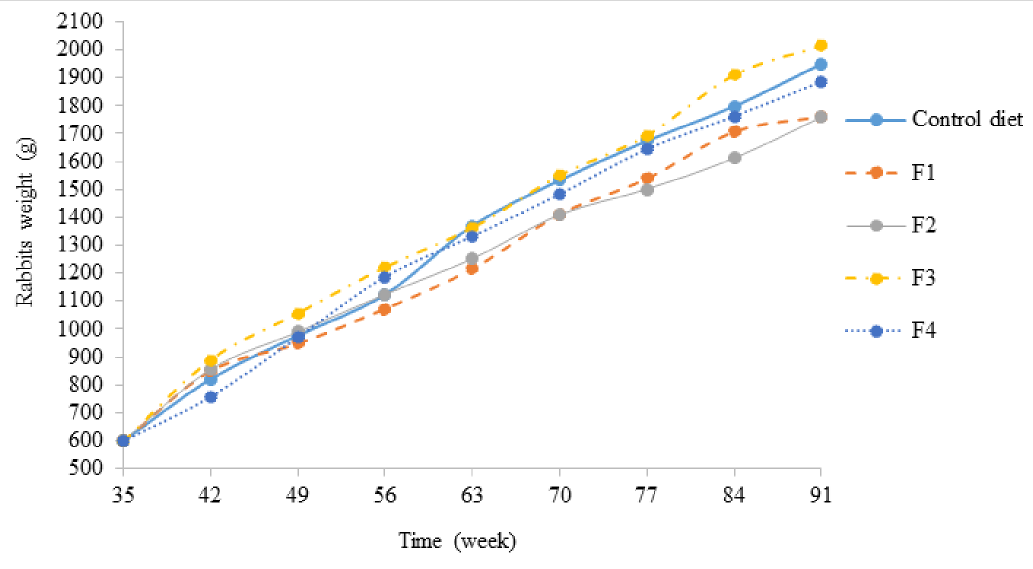

Figure 2: Variation in weight and weight gain of rabbits over 8 weeks

Health status of the rabbits

Table 4 shows the results of the impact of feeding formulas on the health status of rabbits. The F1 and Control diets had mortality rates of 10% while no deaths were observed in rabbits fed the F2, F3 and F4 diets. The morbidity rate was 20% for all animals fed the different formulated diets except for the F3 diet, which had a rate of 10%. The calculation of the health risk index derived from the two previous parameters showed a higher hygiene risk in the F1 diet and the control diet, which was 30%.

Table 4: Apparent health status of the animals

Diet					
Parameters (%)	F1	F2	F3	F4	**Control**
Workforce	30	30	30	30	30
Mortality rate	10 (3)	00 (0)	0(0)	00(0)	10(3)
Morbidity rate	20(6)	20(6)	10(3)	20(6)	20(6)
Survival index	30(9)	20(6)	20 (6)	20(6)	30(9)

Biochemical parameters of the rabbits

The blood parameters of rabbits fed the different diets are presented in Table 5. All the levels obtained did not show significant differences between them for all the diets and for all the parameters measured. Cholesterol, creatinine and urea levels were within the range of the standard, whereas triglyceride levels were above the standard.

Table 5: Biochemical composition of blood serum (mmol/L)

Diet						
Parameters	**F1**	**F2**	**F3**	**F4**	**Control**	**Standards value**
Cholesterol	0.53 ±0.11 ^{a}	0.85 ±0.34 ^{a}	0.845±0.17 ^{a}	0.865 ±0.19 ^{a}	0.64 ±0.11 ^{a}	0.36-0.87
Creatinine	8.5 ±2.12 ^{a}	7.5 ±2.12 ^{a}	9.5 ±0.71 ^{a}	7.5 ±0.71 ^{a}	10 ±1.41 ^{a}	4.3-11.3
Blood glucose	1.66 ±0.035^{a}	1.40 ±0.06 ^{a}	1.59 ±0.20 ^{a}	1.635 ±0.33 ^{a}	1.65 ±0.01^{a}	-
Phosphorus	85 ±16.97 ^{a}	68.5 ±12.02^{a}	66 ±9.9 ^{a}	63 ±1.41 ^{a}	69 ±2.83 ^{a}	-
Triglycerides	0.985 ±0.02 ^{a}	0.925 ±0.20^{a}	0.95 ±0.66 ^{a}	1.12 ±0.47 ^{a}	0.52 ±0.04 ^{a}	0.46-4.85
Urea	0.32 ±0.03 ^{a}	0.31 ±0.00 ^{a}	0.29 ±0.04 ^{ab}	0.21 ±0.05 ^{b}	0.305±0.02 ^{a}	0.29-0 .78

Values followed by standard deviations represent means obtained after three replicates. For each row of the table, values that are not assigned the same letter are significantly different at P < 0.05.

Pellet production costs

Table 6 shows the cost price of raw materials and the estimated cost price of formulated pellets. The protein-rich ingredients were the most expensive. Soybean meal was obtained at 360 FCFA per kilogram, fishmeal at 340 FCFA/kg, cottonseed meal at 250 FCFA/kg, cashew residues at 200 FCFA/kg, and copra meal at 160 FCFA/kg. Carbohydrate and fibrous inputs such as corn and rice bran were the least expensive (80 and 60 FCFA/kg, respectively). Wheat bran costs 110 FCFA/kg. The cost price of each formulated feed depends on the amount of incorporation of each raw material. The prices per kilogram of the formulated diets ranged from 124.5 FCFA (F1 diet) to 213 FCFA (F4 diet), taking into account transportation and electricity. The F4 diet was the most expensive of the formulated diets. It was still less expensive than the control diet by 35 FCFA. All the feeds formulated with agricultural residues were cheaper than the control feed, which is sold at 6000 FCFA per 25 kg bag or 240 FCFA per kg. This is twice the price of the F1 feed. The cost of transport during the collection of inputs was 6000 FCFA. That is 30 FCFA per kg for the 200 kg of formulated food. The cost of feeding a rabbit for 56 days on the F2 diet was 724 FCFA which was the least expensive, followed by the F1 diet (744 FCFA) and the F3 diet (845 FCFA). Of the experimental diets formulated, diet F4 was obviously the most expensive (1163 FCFA). However, its price was lower than the amount paid for the control diet (1628 FCFA). The purchase price of the control diet was almost double the price of the F1 diet used.

Table 6: Formulated diets costs

		F1		F2		F3		F4	
Principal ingredients	**Price per kg (FCFA)**	**Incorporation rate (%)**	**Ingredient price (FCFA)**	**Incorporation rate (%)**	**Ingredient price (FCFA)**	**Incorporation rate (%)**	**Ingredient price (FCFA)**	**Incorporation rate (%)**	**Ingredient price (FCFA)**
Rice bran	60	20	12	20	12	20	12		-
Corn bran	80	10	8	10	8	20	16	15	12
Wheat bran	110		-		-		-	15	16.5
Soybean cake	360	20	72		-	10	36		-
Cottonseed cake	250		-	20	50	10	25	10	25
Fish flour	340		-	20	68	10	34	10	34
Copra cake	160		-		-		-	25	40
Cashew residue	200		-		-		-	25	50
Production costs (electricity + transport)	32.5		32.5		32.5		32.5		32.5
Price of the diet per kg (FCFA)	-		124.5		170.5		155.5		213
Cost of quantities consumed per rabbit (FCFA)	582		744		724		845		1163

Carcass yield of the rabbit

The results of the carcass yields are presented in Table 7 below. There were no significant differences in the values obtained. All values are significantly identical to each other at P > 0.05 for all diets and for the Control. The average carcass yield for all diets was 62.471 ± 2.23%.

Table 7: Carcass Yield of the rabbit

Diet					
Parameters	**F1**	**F2**	**F3**	**F4**	**Control**
WBS (g)	1721 ±210,71^{ab}	1653.33 ±124.93^{ab}	1852.33 ±80.00^{a}	1513 ±0.00^{b}	1952.33±52.72^{a}
CS (g)	1116±137.87^{abc}	991.67 ±47.72^{bc}	1148.67 ±52.63^{ab}	934±0.00^{c}	1209.33 ±79.185^{a}
CY (%)	64.86±1.88^{a}	60.082 ±2.58^{a}	62.01±0.29^{a}	61.73^{a} ±0.00	61.90 ±2.35^{a}

Values followed by standard deviations represent means obtained after three replicates. For each row of the table, values that are not assigned the same letter are significantly different at P < 0.05. (WBS: Weight Before Slaughter (g); CS: Carcass Weight (g), CY: Carcass Yield).

Organoleptic characteristics of the rabbit meat

Regarding the organoleptic characteristics, table 8 presents the scores produced by the panelists. The values for criteria such as taste, smell and tenderness were statistically identical (P> 0.05). The average scores obtained for odor were 3.42 ± 0.93, for taste 3.45 ± 1.10 and for tenderness 3.48 ± 1.07. The overall scores for F1, F2 and F4 were statistically identical and significantly higher than F2 and the Control.

Table 8: Organoleptic and hedonic parameters of meat from rabbits fed F1, F2, F3, F4 diets and the control

Diet					
Parameters	**F1**	**F2**	**F3**	**F 4**	**Control**
Odor	3.63 ± 0.97^{a}	3.25 ± 1.17^{a}	3.46 ± 1.22^{a}	3.63 ± 0.85^{a}	3.14 ± 0.93^{a}
Juiciness	3.44 ± 0.99^{a}	3.14 ± 1.02^{b}	3.63 ± 0.98^{a}	2.9 ± 1.10^{c}	3.49 ± 0.99^{a}
Taste	3.41 ± 1.18^{a}	3.17 ± 1.10^{a}	3.26 ± 1.20^{a}	3.5 ± 1.10^{a}	3.21 ± 1.21^{a}
Intense odor	3.4 ± 1.15^{a}	3.24 ± 1.33^{a}	2.93 ± 1.05^{a}	3.38 ± 1.12^{a}	3.38 ± 1.17^{a}
Visual aspect	3.19 ± 0.90^{ab}	3.33 ± 1.11^{a}	2.55 ± 0.98^{c}	2.69 ± 0.96^{c}	2.90 ± 1.17^{ab}
Softness	3.53 ± 0.74^{a}	3.22 ± 1.07^{a}	3.58 ± 0.95^{a}	3.33 ± 0.86^{a}	3.75 ± 0.97^{a}
General appreciation	2.66 ± 0.79^{ab}	2.48 ± 0.89^{b}	2.69 ± 0.76^{ab}	3.15 ± 0.73^{a}	2.53 ± 1.25^{b}

Values followed by standard deviations represent means obtained after three replicates. For each row of the table, values that are not assigned the same letter are significantly different at P < 0.05.

DISCUSSION

The diets, although derived from agricultural residues, allowed the growth of the young rabbits in size and weight. Therefore, they were complete and contained all the nutritional resources essential for the growth of the rabbits. According to Gidenne *et al*., (2015), in fattening, rabbits mainly need energy, protein, and fiber in balance. By-products such as soybean and cottonseed meal, cashew nut meal, and fish meal are strong protein providers. They contain a minimum of 45% protein (FAO, 2014; Gidenne *et al.*, 2015). Spent grain contains between 32 and 35% of dry matter, depending on the grain used. These by-products have significant fiber content that is also favorable for rabbits. Therefore, they provide protein while providing rabbits with a minimum level of fiber (Vilariño *et al*., 2007). Corn, wheat and rice bran, spent grain and grasses are important sources of fiber, with 40% of the fiber being provided by these products. The ingestion of fibrous feed combined with a good protein level allows rabbits to achieve good growth performance (Gidenne *et al.*, 2010). Thus, all the by-products combined between them allowed them to satisfy the needs of rabbits. This means that the feed combinations made from the residues used provide the quantity and quality of nutrients essential for the growth of the rabbits.

In terms of growth parameters, the GMQ obtained with the F3 and Control diets was higher than the weight gains obtained with the F1, F2 and F4 diets. These performances could be explained by the qualitative protein supply of the residues because, to ensure optimal growth of the animals, dietary proteins must provide them with amino acids in a balanced way (Carabano *et al*., 2008). Indeed, plant proteins generally have a limited content of some essential amino acids, which is not the case of animal proteins, which often have surpluses compared to egg, which is the reference protein (Vliet *et al*., 2015). This is the example of corn meal and cottonseed cake deficient in lysine, which is an essential amino acid (Vilariño *et al*., 2007) and essential for bone growth and weight (Sharma *et al*., 2004), while fishmeal contains an excess of it (Médale and Khausik, 2009). This is an example of complementarity that allows compensating for nutritional deficits or excesses of a particular ingredient in order to obtain an ideal balance for animal growth. This justifies the realization of a skilful mixture of both animal and vegetable sources to meet the needs of the rabbits. This was the case with the F3 and F4 diets, which contain a greater diversity of ingredients rich in both animal and vegetable proteins (fish meal, soybean and cottonseed meal, and brewer's grains for F3 and fish meal, cottonseed and copra meal, and cashew nuts for F4 diet) while the F1 and F2 diets contain two. Brewer's grains combined with soybean meal were used for the F1 diet, and cottonseed meal combined with fish meal for the F2 diet. Also, the combination of certain plant families (especially cereals and legumes) in the same diet can ensure satisfactory intakes for all essential amino acids (FFAS, 2019). It is therefore possible to perform plant supplementation by combining two protein-rich plant sources; this was done for the F1 diet. The different combinations of protein sources would have made it possible to meet the essential amino acid requirements of the rabbits, thus quickly compensating for deficiencies and promoting better weight growth. However, the low weight gain observed in animals fed the F2 diet could be attributed to the presence of gossypol resulting from the incorporation of 20% cottonseed meal in this diet. According to Paiano *et al*., (2006), cottonseed cake levels above 15% in the diet have adverse effects on the zootechnical performance of animals. It prevents the bioavailability of certain amino acids essential for growth, such as lysine, by creating a "gossypol-lysine" complex through the fixation of its aldehyde functions on the amino groups of lysine (Gamboa *et al*., 2001; Azman and Yilmaz, 2005). In turn, this complex decreases the protein value of the cottonseed cake ingredient in formulations. In addition, gossypol inhibits the activity of enzymes in the gut lumen such as pepsinogen, pepsin, and trypsin. It would be advisable to feed monogastric animals dehulled cottonseed cakes obtained by improved oil extraction processes because they are less rich in gossypol. The F4 diet, although containing 4 sources of protein, had lower weight gain than the F3 and control diets. Gossypol could be the reason for this, but it could also be due to the low rate of feed intake. Note that the weight gains obtained with the different experimental diets are higher than those of Bouaténé (2013) and close to those obtained by Richard *et al*., (2017).

With respect to daily food intake rates, they changed progressively over the course of the experiment for all diets. During the experiment, it was observed that the consumption between days 35 and 49 was significantly lower than the food consumption at the end of the experiment. This difference could be explained by the different physiological stages that the rabbits go through. Indeed, Gidenne and Lebas (2005) showed that food consumption was strongly dependent on the age of the rabbits. Rabbits regulate their intake according to their energy needs. The more energetic the food, the less it will be consumed. Protein content can also modify feed intake due to its balance of essential amino acids. For example, an excess of methionine reduces the intake of growing rabbits by at least 10% (Gidenne *et al*., 2005). Since the formulated diets had higher protein and fiber content than the control diet, this could justify their lower intake compared to the control diet. This analysis can be seen with the F4 diet, especially since it contains a significant amount of fat (16%) in addition to its good fiber and protein content. Moreover, since the diets were formulated without a palatability enhancer, unlike the molasses-containing control diet, they were immediately pushed back at the beginning of the experiment. As a result, the formulated diets were consumed less than the control diet. This observation was also made by Fekete and Lebas (1983). Also, the F4 and F2 diets that were consumed the least had pellets that were less hard and easily crumbled due to their high fat content (copra cake and cashew nuts). The animals therefore left powdered feed in the feed troughs. It has been shown by some authors that, in free choice, 97% of rabbits prefer a pelleted feed rather than a meal (Harris *et al*., 1983; Gidenne and Lebas (2005). In addition, a meal feed appears to disrupt their circadian cycle of ingestion (Gidenne *et al*., 2015).

As for the feed conversion ratio, it provides information on the feed efficiency of a diet in reverse order. It gives the amount of feed to be consumed in kg to obtain 1 kg of live weight. The low indexes recorded for the F4 diet for high daily weight gains show the effectiveness of this diet. Feed efficiency is a key indicator for judging the performance and profitability of a farming system (Gidenne *et al*., 2013). In rabbit farming, the feed efficiency index for flocks fed pelleted feed increased from 3.8 to 3.4 (Gidenne *et al.*, 2013). Our values obtained are conformed. They are twice lower than those obtained by Yao *et al*., (2016), who obtained consumption indices of between 7 and 8 by feeding their rabbits with leafy vegetables. Hence the interest in using pellets to feed rabbits because small amounts of pelleted feed allow an optimum result.

The carcass yields obtained are above 60%. In a study by Pertusa *et al*., (2014), the rearing factors most likely to influence slaughter yield were identified. These were weaning weight, the density of rabbits in the feeder cage, and age at slaughter. In the present study, the experimental conditions were set up and the quality of the elaborated diets allowed a good carcass yield. The observed values are higher than the percentages obtained by Lounaouci-Ouyed *et al*., (2009) and Yao *et al*., (2016), who obtained percentages between 50% and 55%.

Due to their high sensitivity, sick rabbits were mostly affected by bloating, followed by diarrhea with or without mucus in the stool. This was not necessarily due to the consumption of the diets, but it resulted in low food intake and dehydration. These transient symptoms have led to the death of some rabbits in other cases. Morbidity is usually associated with a disturbance in the feeding behavior of the subject and the poor quality of the feed, which are caused a decrease in growth. Affected subjects were excluded from growth performance calculations during the disease period.

Serum concentrations of biochemical parameters are dependent on the feed used for feeding (Atchade *et al*., 2019). These include renal parameters (urea and creatinine), mineral metabolism parameters (sodium, potassium, calcium, phosphorus, chlorine) and liver parameters (glucose, cholesterol, and triglycerides). The biochemical constants recorded during this study did not reveal any adverse impact on the health of the animals. In addition to energy requirements, hemostatic mechanisms are thought to be involved in the regulation of food intake in rabbits through the nervous system and blood levels of compounds used in energy metabolism (Gidenne *et al*., 2010). The use of by-products did not lead to an imbalance in blood sugar levels in the test subjects.

Similarly, feed also have little influence on the organoleptic quality of the meat. All experimental diets produced meat with organoleptic characteristics that were generally appreciated by the tasters. The odor and taste descriptors gave significantly identical scores for all diets. Tenderness is perceived as the ease with which a piece of meat can be sliced and chewed. It is the most important sense for a consumer (Touraille, 1994). It was assessed at the same level as the meat of animals fed on all manufactured diets. The thinness observed in the meat of rabbits fed the F2 diet could be related to the low fat content of this diet. In addition, a study has shown that the incorporation of fish oil can enrich the ration with long-chain omega 3 (Sauvant *et al*., 2002).

Considering the feed prices during the experiment, the amount spent for the production of the F1 diet is half of the amount spent for the control diet, and at the end of the experiment, the average weight gain is only 3 g. This diet could still allow the rabbit farmer to reach the desired slaughter weight if he extends the rearing period by eight days. Also, the F3 diet that achieved the best performance is 40 % cheaper than the commercial diet. Then, the formulated diets have allowed considerably reduced the price of pelleted feed. The F1 and F3 diets could be used very well to have a productive breeding while saving on the purchase price of pellets.

CONCLUSION

Thus, the overall objective of this work, which was to contribute to the improvement of the quality and cost of production of rabbit feed, was to show that all the formulated diets produced rabbits of marketable size after 56 days of experimentation. The diets did not cause any adverse effects on the health status of the animals. This study also revealed that variability in protein sources is the key to a successful grower feed as the F3 formula combination provided the best average daily weight gain. This diet also allowed the rabbits to meet their nutritional needs more quickly, which in turn increased their body mass, an essential element in determining the selling price of the rabbit. The agricultural residues make it possible to considerably reduce the production costs of pelleted feed. Thus, the composition of the ingredients of this diet has made it possible to reduce the price of the pelleted feed by 40%.

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