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Leafy feed supplementation, rabbit growth performance and meat quality: Case study of *Ipomoea aquatica*

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Thirty-six local young rabbits of 42 days old were used to evaluate their growth performances and sensory characteristics of their meats based on the type of feed. The rabbits were divided into three groups of twelve animals each, that were fed for 56 days with one of three diets: Commercial feed (Cfe), commercial feed supplemented with water spinach (*Ipomoea aquatica*) (Cfw) and feed composed only of water spinach (Wsp). At the end of the fattening period, rabbits were slaughtered at 1561.8 ± 105.3 g, for physicochemical analysis and sensory evaluation. Meat from rabbits fed with Cfw had protein and fat contents significantly higher (P< 0.05) than meat from rabbits fed with the two other diets. However, the meat from rabbits fed with Wsp had pH and moisture content significantly lower (P < 0.05) and significantly higher (P < 0.05) than those of rabbits fed with the two other diets respectively. The sensory analysis showed that the meats obtained from rabbits fed with the three types of feed were accepted. The panellists particularly appreciated meat from rabbits fed with Cfw for tenderness, juiciness and succulence.

Key words: *Ipomoea aquatic,* rabbit, fattening, meat quality, sensory.

INTRODUCTION

Proteins are essential and play an important role in the growth, reproduction, immunity, maintenance, and development of human tissues. Proteins are made up of several amino acids and among these amino acids, eight are known as essential and cannot be synthesized by human body (Elmadfa and Meyer, 2017; Westerterp-plantenga, 2003). Although, proteins are found in many vegetable foods (Guéguen et al., 2016) and animal foods (Iko Afé et al., 2020; Prawirodigdo et al., 2005; Wafar and Tarimbuka, 2016), only animal proteins contain the eight essential amino acids that our bodies cannot synthesize (Comerford and Pasin, 2016; Elmadfa and Meyer, 2017; Martens and Westerterp-plantenga, 2014). Indeed, animal proteins are of very good quality and contain in balanced proportions, all essential amino acids useful for human body. Animal proteins often come from food

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products such as meat. Meats are edible parts of domestic animals, wild and farm animals with a good nutritional value such as proteins, lipids, amino acids, vitamins and minerals (Duchène et al., 2010; Iko Afé et al., 2020). In Benin, animal breeding plays an important role as poverty reduction and food security contribution. Among animal breeding, special attention was paid to short-cycle animal species such as rabbit (Hongbété et al., 2016; Houndonougbo et al., 2012). Breeding of Rabbits (*Oryctolagus cuniculus*) well managed can allow the production of more than 200 rabbits per female per year (Larzul et al., 2005; Ouyed et al., 2011; Piles et al., 2004). Like poultry, rabbit meat is a lean meat (Barbut, 2015; Zeferino et al., 2016), particularly well appreciated among Beninese population and does not suffer from any taboos like other meat such as pork which consumption is forbidden to Muslims (Youssao et al., 2008) and restricted to most of animist (Iko Afé et al. 2020).

In Benin, several studies have been undertaken on rabbit (Adanguidi, 2020; Konmy et al., 2020; Kpodekon et al., 2006; Lebas et al., 2012). Most of these studies focused on how to improve the feed of rabbit in aim to reduce production cost and to improve the nutritional quality of rabbit (Adande et al., 2017a; Adanguidi, 2020; Hongbété et al., 2016; Houndonougbo et al., 2012). Many tropical plants with good nutritional quality are available and are able to satisfy nutritional needs of rabbits which are grass-eating (Adande et al., 2017b; Cullere and Zotte, 2018). Kimsé et al. (2014) evaluated the use of plants (*Centrosema pubescens, Albizia lebbeck* and *Andropogon gayanus)* as supplementation in rabbit feeding and conclude that these plants are an alternative to minimize production costs but have no significant effect on total ingestion (45-91 days), body weight gain and carcass productivity. However, to our best knowledge none of these studies have assessed the nutritional and sensory quality of the rabbit meat fed with water spinach especially in Beninese conditions to reduce the production cost and improve rabbit meat quality. The purpose of the present work is to study the effect of the water spinach (*Ipomea aquatica*) on the growth performance of young rabbits during fattening and to assess the sensory quality of rabbit meat.

MATERIALS AND METHODS

Experimental sites

The experiment was carried out in the AgroNutriIPlus farm (ANP Farm) (latitude 9°15'N and longitude 2°30'E) about 3 km from university of Parakou, located in Parakou commune, Borgou province, Benin.

Animal management and sampling

From August to December 2019, thirty-six baby rabbits (*O. cuniculus*) with average live body weight of 665.8 ± 0.4 g at 42 days old were used for the experiment at the AgroNutriIPlus farm (ANP Farm, Benin) for eight weeks. The animals were divided in 9 batches of 4 rabbits each. The 4 rabbits of each batch were housed into galvanized metal cage of 75 cm length, 45 cm width and 30 cm height. Each cage is equipped with a drinker, a feeder and a recovery system placed below each cage to collect wasted food. Cages were installed in three rows of 9 cages each and were at 80 cm from the ground and 160 cm from the roof. Before the start of the experiment, Amprolium, 2 g/L for three days and SULFA33, 5 ml/L of water for five days were administered to the young rabbits for the preventive control of coccidiosis. Oxytetracycline 10% has been given to the young rabbits for the prevention of various infections. Also, the rabbits were dewormed using IVERMECTINE* injection, 1 mL/kg body weight.

Three experimental feed were used: commercial feed (Cfe), commercial feed supplemented with water spinach (*I. aquatica*) (Cfw) and a feed only composed of water spinach (Wsp). The commercial feed was locally manufactured (in Benin) by a veterinarian society service (control diet). This commercial feed was constituted of floury food rich in wheat bran, rice, palm kernel cake and cotton kernel cake. The water spinach was daily harvested at 4.30 p.m. from fields around the AgroNutriIPlus farm. The Cfe and the Cfw had similar digestible energy and crude proteins (Table 1).

To differentiate the animals, they were divided into three feed groups (Cfe, Cfw, Wsp) of 12 animals per group. They were marked with a code on the external face of their ear with Cfe for the first group, Cfw for the second and Wsp for the last group. To allow identification of each subplot during weighing, the rabbits were numbered using a marker on the inside of the ears with the numbers (1, 2, 3, 4 for the first subplot; 5, 6, 7, 8 for the second subplot; 9, 10, 11, 12 for the third subplot). The cages were numbered and arranged so that all animals were exposed to the same microclimatic condition. At the start of the experiment, all three batches of rabbits were homogeneous, that is to say that each group had approximately the same body mass (665.8 ± 0.4 g). To start the experiment, a three-day food transition was made to allow the rabbits to adapt to the ration to be tested. Each young rabbit was fed two times a day at the rate of 100 g per meal served. After individual weighing of the animals on D0, the day the experiment was started, the weight of the animals was recorded weekly on a fixed day for eight weeks of fattening. The weighing was carried out with a brand "WeiHeng" digital electronic balance (Guangdong, China) with a capacity of 10 kg, with an accuracy of ± 1 g. The experiment took eight weeks and finished when rabbits were fourteen weeks old. At the end, three rabbits per feed group were slaughtered. They were bled by cutting the jugular vein and the carotid artery. Carcasses were chilled at 4°C for 2 h and then weighed. Identic carcasses pieces were grilled using charcoal for 30 min without seasoning (Figure 1) to avoid any bias such as effect of seasoning on sensory quality of rabbit meat during sensory evaluation and physicochemical composition.

Physicochemical analysis

Physicochemical analyses were conducted on 3 grilled meat samples per feed group. They were determined according to the Association of Official Analytical Chemists (AOAC) procedure (AOAC, 1995). Two grams of ground meat sample were oven dried at 105°C for 24 h until a constant weight for moisture content determination. The ash content was obtained by mineralization of 10 g of meat sample in a muffle furnace (Pyrolabo, France) set at 550°C for 12 h. Crude protein was calculated as nitrogen amount (Kjeldhal method) multiplied by 0.625 per 100 g of meat. The fat content of meat sample was determined with Soxhlet extraction method using petroleum ether as solvent. The pH value of meat samples were determined by homogenizing meat samples with distilled water and measured using pHmeter (Hanna Instrument HI 9318) according to reference method (ISO-2917, 1999). The tenderness was measured using texture analyser to shear rabbit meat samples.

Table 1. Ingredient and chemical compositions of growing rabbit's diets.

Raw material	Commercial feed (Cfe) (Hongbété et al., 2016)				Commercial feed + water spinach (*Ipomoea aquatica*) (Cfw) (Hongbété et al., 2016; Samkol, 2009)				*Water spinach (Ipomoea aquatica) (Wsp)* (Samkol, 2009)			
	Quantity (kg)	**Energy (kcal/kg)**	**Crude protein (%)**	**Crude fibre (%)**	**Quantity (kg)**	**Energy (kcal/kg)**	**Crude protein (%)**	**Crude fibre (%)**	**Quantity (kg)**	**Energy (kcal/kg)**	**Crude protein (%)**	**Crude fibre (%)**
Soybean	10	320	4.25	0.74	10	320	4.25	0.74	-	-	-	-
Maize bran	15	489	1.35	0.33	15	489	1.35	0.33	-	-	-	-
Palm kernel cake	23	621	4.255	3.45	20	621	4.255	3.45	-	-	-	-
Cotton kernel cake	2	55.8	0.82	0.26	2	55.8	0.82	0.26	-	-	-	-
Wheat bran	30	744	4.5	3.18	30	744	4.5	3.18	-		-	-
Rice bran	17	306	2.04	4.25	17	306	2.04	4.25	-	-	-	-
Oyster shell	2.5	-	-	-	2.5	-	-	-	-	-	-	-
Salt	0.5	-	-	-	0.5	-	-	-	-	-	-	-
Water spinach (Ipomoea aquatica) leaves	-	-	-	-	3	0.6	0.78	0.42	100	19	26	14
Total	100	2535.8	17.215	12.2	100	2536.4	18	12.63	100	19	26	14

The shear force of grilled meat was determined using a Stevens texture analyser (Stevens-LFRA texture analyser, model TA 1000, serial n°2210, Harlow. U.K.). Before the test, a pre-test speed 4.2 mm/s and test speed 10 mm/s, trigger type 10 g were done. Each meat sample was sheared with a single blade three times perpendicular to the muscle fibres orientation, with a 1.5 cm distance from each cut. Tenderness was measured as the peak shear force (N), required to finally shear through the sample.
The average of the maximum force of three measurements was used for data analysis (AMSA, 2015).

Sensory evaluation

A total of 30 semi-trained consumers were recruited from the restaurant of grilled meat called "la grillade KDK" in Parakou, Benin. Information regarding socio-demographics characteristics and consumption habits were collected via a questionnaire before the sensory evaluation of the samples.

For this test, coded grilled rabbit meat pieces were presented to each participant to evaluate their preference for specific sensory attributes of the products. The degree of golden colour, tenderness, succulence, juiciness, fibrousness and flavour were selected as the main quality attributes (Table 2) of rabbit meat. Each participant was asked to score the acceptability of rabbit meat on the basis of the six attributes using a 9-point hedonic scale which varied from 'extremely dislike' to extremely like' (Kindossi et al., 2013; Tomlins et al., 2005).

Statistical analysis

All the collected data were subjected to descriptive statistics, analysis of variance (ANOVA), correlation and principal component analysis (PCA) using Statistica (StatSoft France (2006), version 7.1). One-way ANOVA was used to evaluate the effect of feed on the growth performance of rabbit and the rabbit meat quality. The differences between groups were evaluated using Dunnett test with commercial feed (Cfe) as control. The statistical significance level was set at $P < 0.05$. The PCA was done to determine relationships between physicochemical parameters and sensory attributes.

RESULTS

Feed intake of growing rabbits

Figure 2 presents the daily feed intakes of rabbits fed with the three foods according to the experimental weeks. Between the beginning (first week) and the end (week 8) increased from 39.8 g to 78.5 g. Likewise, daily feed intakes of rabbits\ fed with Wsp increased from 42.5 g at the beginning of the experiment to reach 87.3 g. The increase of feed intake was more important with the abundant level of crude fibre in feed (Table 1).

Growth performance of rabbits and feeds efficiency

Figure 3 presents the growth of rabbits fed with the three foods during the experimental weeks.

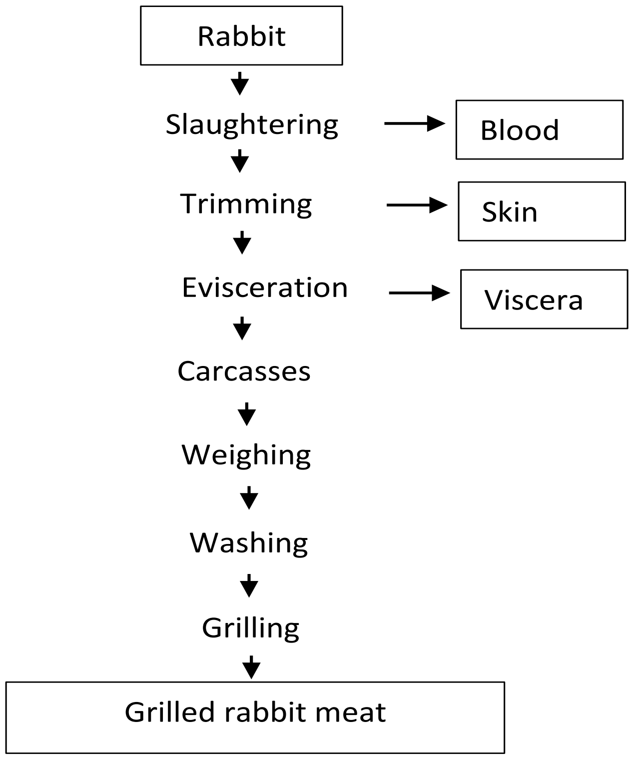

Figure 1. Flow diagram of grilled rabbit meat.

Table 2. Definition of the sensory attributes.

Sensory attribute	Description
Appearance	
Golden colour	The colour observed after cooking of rabbit meat – turning to the dory, the characteristic colour of grilled meat
Consistency	
Tenderness	The force needed to masticate the meat ready for swallowing
Juiciness	Moisture perceived during chewing, from the moisture released by the sample and from the secreted saliva. The degree of juice released while chewing the meat.
Fibrousness	Number and thickness of fibres perceived during chewing.
Taste	
Succulence	The state of being sweet and delicious (full juice and taste good)
Flavour	The combination of taste, odour and tactile stimuli perceived retronasally during chewing – referring to the characteristic flavour of rabbit meat.

At the beginning of the experiment the live body weight of the rabbits was around 650 g while after eight weeks, the live body weight increase till about 1500 g. During the experiment, one rabbit belonging to the rabbit group only fed with the Wsp died from diarrhoea (Table 3). For the three types of feed, the live body weights of rabbits changed slightly in a jagged fashion after eight experimental weeks. However, the live body weights were not statistically different (P > 0.05) between rabbits fed with Cfe (1449.4 g), Cfw (1658.1 g) and Wsp (1578.5 g). The daily weight gain of rabbits fed with Cfw (18.6 g/d) and that of rabbits only fed with Wsp (18.3 g/d) were significantly (P < 0.05) higher than the daily weight gain of rabbits fed with Cfe (14.0 g/d).

Physicochemical characteristic of grilled rabbit meat

The physicochemical parameters of rabbit meat are presented in Table 4. The feed had an apparent effect on

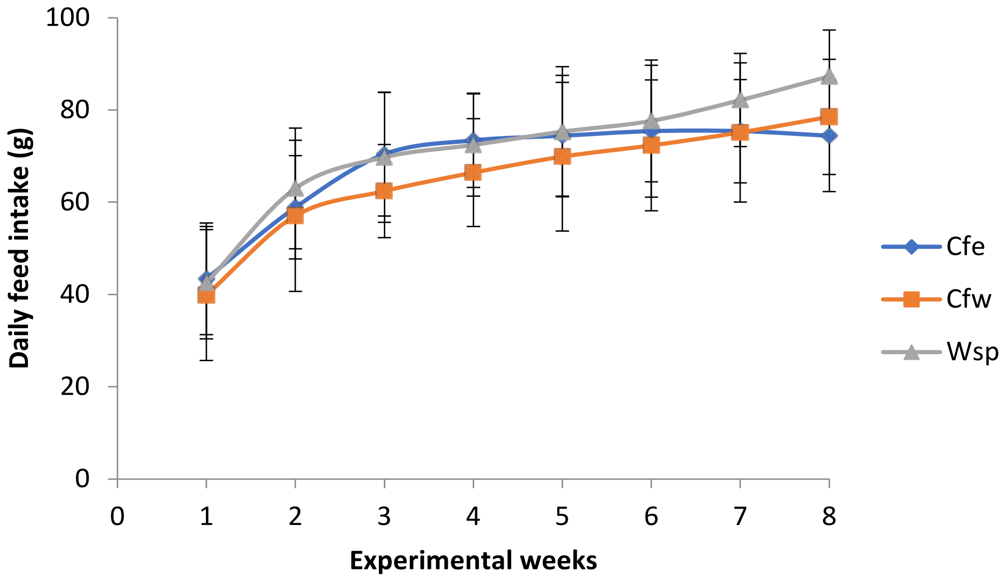

Figure 2. Average daily feed intake of growing rabbits fed with commercial feed (Cfe), commercial feed + water spinach (*Ipomoea aquatica*) (Cfw) and feed composed only of water spinach (Wsp) respectively.

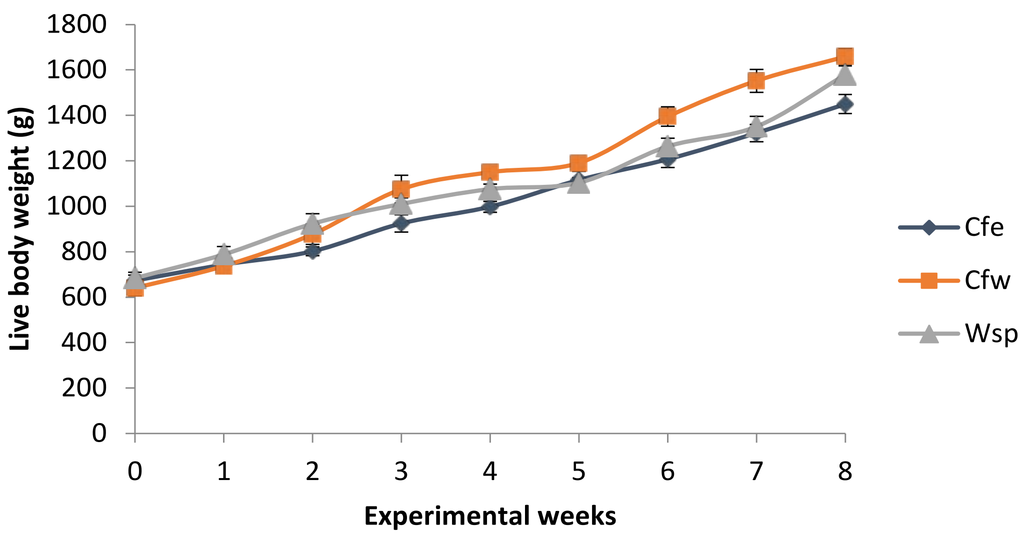

Figure 3. Growth curves of rabbits fed with commercial feed (Cfe), commercial feed + water spinach (*Ipomoea aquatica*) (Cfw) and feed composed only of water spinach (Wsp) respectively.

rabbit meat quality. The pH of rabbit meat ranged from5.76 to 5.85 (Table S1). The meat sample of rabbit fed with Wsp (5.76) had significantly ($P < 0.05$) lower pH than meat samples of rabbit fed with Cfe (5.85).

The moisture content of meat sample of rabbit fed with Wsp (76.9%) were significantly higher ($P < 0.05$) than those of rabbit fed with Cfe (72.3%) and Cfw (71.4%), however there was no significant difference ($P>0.05$) between moisture content of meat sample of rabbit fed with Cfe and Cfw.

Protein content in meat sample of rabbit fed with Wsp (17.5%) were significantly lower ($P< 0.05$) than those of rabbit fed with Cfe (19.3%) and Cfw (19.9%). The fat content of rabbit meat samples varied from 2.4 to 6.9%. The meat samples of rabbit fed with Wsp (3.9 g/100 g) had significantly lower fat ($P < 0.05$) than those of rabbit fed with Cfw (5.7%), but no significant difference ($P > 0.05$) was observed between meat samples of rabbit fed with Cfw and those of rabbit fed with Cfe (4.3%).

Ash content of meat samples of rabbit fed with Cfw

Table 3. Effect of providing concentration on growth performance of rabbits (n = 35).

Parameter	Rabbits fed with		
	Cfe[1]	Cfw[2]	Wsp[3]
Initial number of rabbits (n)	12	12	12
Dead rabbits (n)	0	0	1
Final number of rabbits (n)	12	12	11
Live body weight, g	1449.4±130.6[a]	1658.1 ±105.1[a]	1578.5±73.4[a]
Daily weight gain (g/d)	14.0±0.2[a]	18.6 ± 0.5[b]	18.3±0.2[b]

[1]Commercial feed, [2]Commercial feed + water spinach; [3]Feed composed only of water spinach; n: number of rabbits; [a, b] values with unlike superscripts in the same row differ significantly (*P* < 0.05). ±: Standard error of the least squares means. g/d: gram per day

Table 4. Physicochemical composition of meat from rabbits (n = 9) fed with different diets.

Parameter	Rabbits fed with		
	Cfe[1] (n = 3)	Cfw[2] (n = 3)	Wsp[3] (n = 3)
pH	5.85±0.01[a]	5.83±0.00[ab]	5.76±0.00[b]
Moisture (%)	72.3±0.4[a]	71.4±1.0[a]	76.9±0.7[b]
Protein (%, wet weight)	19.3±0.2[a]	19.9±0.3[a]	17.5±0.3[b]
Fat (%, wet weight)	4.3 ±0.1[ab]	5.7±0.3[b]	3.9±0.6[a]
Ash (% wet weight)	1.0±0.1[a]	1.4±0.1[b]	1.0±0.0[a]
Shear force (N)	1.1±0.0[a]	0.8±0.0[b]	0.4±0.0[b]

[1]Commercial feed; [2]Commercial feed + water spinach; [3]Feed composed only of water spinach; n: number of rabbits
[a, b] values with different superscripts in the same row differ significantly (*P* < 0.05). Mean ± standard error.

(1.04%) was significantly higher (P < 0.05) than the ash of meat samples of rabbit fed with Wsp (1.0%) and Cfe (1.0%). The shear force value provided from the grilled rabbit meat varied from 0.3 to 1.1 N (Table S1). The grilled meat samples of rabbit fed with Cfe had a shear force value (1.1 N) significantly (P < 0.05) higher than those of rabbit fed Cfw (0.8 N) and Wsp (0.4 N).

Sensory characteristic of meat of rabbits fed the three types of food

The test revealed that the consumers (panellists) were composed of 53% males and 46% females and were aged between 24 and 30 representing 53% of the panellists. They had a high education level (63% had a university degree) and were habitual rabbit meat consumers (2-3 times a week in 80% of the cases). Most of them (76%) preferred a grilled rabbit meat (Table S2). The sensory attributes of meat of rabbit fed with different experimental diets were evaluated by 30 panellists, using hedonic scale of nine points (Table 5). The result showed no significant difference (P > 0.05) regarding the colour and flavour among meat samples of rabbits fed with Cfe and Wsp. However, significant differences (P < 0.05) were observed in tenderness, succulence, juiciness, fibrousness and overall acceptability of meat samples of rabbits fed with the three experimental diets. The meat samples of rabbits fed with Cfw had the highest acceptance score in tenderness (7.1), juiciness (6.5) compared with other meat samples of rabbits fed with Cfe and Wsp respectively. For descriptors associated with the taste, meat samples of rabbits fed with Cfw were more succulence (7.5) than meat samples of rabbit fed with Wsp. Moreover, meat samples of rabbits fed with Cfw were more acceptable (7.2) than other meat samples of rabbits fed with the two other diets.

DISCUSSION

Feed intake, live body weights of rabbits and feeds efficiency

At the end of the experiment, the three types of feed tested induced a very low mortality rate (3%). Foods had significant effect on daily weight gain however, no significant effect was observed on feed intake and on the live body weights. The higher feed intake obtained was 97.3 g/d in group of rabbit fed with water spinach. Water spinach has great potential for use as a feed vegetable for people and animals and therefore the use of this plant would have boosted the growth performance of rabbits. It has adequate amounts of nutriments and water to avoid physical and psychological suffering from hunger and thirst. The high water content in water spinach might

Table 5. Sensory attributes of meat from rabbits fed with different diets using hedonic scale of nine points.

Descriptors	Rabbits fed with		
	Cfe[1]	Cfw[2]	Wsp[3]
Golden colour	5.4±0.1[a]	5.4±0.1[a]	5.3±0.2[a]
Tenderness	6.0±0.2[a]	7.1±0.1[b]	7.6±0.8[c]
Succulence	7.0±0.1[a]	7.5±0.1[ba]	5.1±0.1[c]
Juiciness	5.3±0.1[a]	6.5±0.1[b]	4.8±0.1[ac]
Fibrousness	4.8±0.1[a]	6.3±0.1[b]	6.7±0.3[b]
Flavour	6.0±0.1[a]	6.2±0.2[a]	6.2±0.1[a]
Overall acceptability	6.3±0.1[a]	7.2±0.1[b]	5.1±0.1[c]

[1]Commercial feed
[2]Commercial feed + water spinach
[3]Feed composed only of water spinach
[a, b,] values with different superscripts in the same row differ significantly ($P < 0.05$).
Mean ±: Standard error

contribute to the feed intake (Nielsen et al., 2020). The feed intakes obtained in the experiment were close to those record in growth performance of rabbits fed palm-press fibres based diets (Houndonougbo et al., 2012). The final live body weights of rabbits (1449.4 to 1658.1 g) in all dietary treatment at 56 days were lower than the findings (1718 to 1805 g) reported for rabbits fed with improved diets with different supplemented amount of palm-press fibres at the same age (Houndonougbo et al., 2012). The final live body weights of rabbits were more close to the 1650 g obtained at 35 days of fattening for rabbits fed with an improved diet based water spinach (Adande et al., 2017b). These differences could be due to the nutrients qualities of the ingredients incorporated. Also, Hongbété et al. (2016) found with the same commercial feed used in the present study a lower live body weight (1148.3 g) for the same fattening age. This difference could be due to the initial weights of the rabbits used during the experience (660 g against 342 g) and environmental factors (test period, sanitary conditions, etc.). The higher live body weight was found in group of rabbit fed with the Cfw, we can claim that the use of this plant induces better performance for rabbits without any adverse effect on their survivability. Moreover, water spinach is a plant widely present everywhere in Benin, rich in high nutrients as proteins, vitamins and minerals.

Effect of experimental diets on physicochemical characteristic of grilled rabbit meat

The rabbits were bred and reared for meat production. The results of physicochemical characteristics of rabbit meat showed that pH, moisture, protein, fat, ash and shear were significantly ($P < 0.05$) affected by the diets. The pH values of rabbit meat (5.75 to 5.85) are the most important physicochemical characteristic to appreciate the quality of rabbit meat. The pH is the result of the breakdown of muscle glycogen by post-mortem glycolysis leading to synthesis of lactic acid from pyruvate and the reduction of muscle pH. The pH reduction is needed for muscle conversion into meat (Lehninger et al., 2008).

The higher proportion of protein in meat of rabbit fed with Cfw could be due to the presence of protein in water spinach, which supplement the protein available in the Cfe. Therefore, the richness of nutrients in leafy vegetables is a significant asset for increasing these nutrients in meat. These protein values were similar to those reported after using water spinach as forage in rabbit feed (Kosina et al., 2017). The fact that the means of fat recorded in meat of rabbit fed with the three experimental diets were below 10% shows that rabbit meat can be considered like lean meat as reported by Cullere and Zotte (2018). According to Gigaud and Combes (2007), rabbit meat could be considered as dietetic food.

The ash content in rabbit meat fed with Cfw was also significantly higher than those of meat from rabbits fed with two other diets. This finding indicates that rabbit meat contained higher mineral (calcium, potassium, phosphorus, magnesium, copper and selenium) due to the composition of water spinach. The same observation was done for rabbit meat fed with selenium supplemented diet which contained higher amount of selenium than control rabbit meat (Dokoupilová et al., 2007; Mattioli et al., 2019).

Lower values of shear force recorded were needed to cut the meat sample. This result suggested that the supplementation of water spinach had an effect on the rabbit meat weak firmness. Our results were lower than others findings reported (Gondret et al., 2005; Pascual and Pla, 2008). This difference could be due to higher Sensory attributes are considered as most important characteristics affecting food acceptability at purchase(Carrilho et al., 2009; Cullere et al., 2018; Martinez-alvaro et al., 2018; Vasta et al., 2008). The results obtained from the sensory evaluation show that meat of rabbit fed with the three experimental diets were

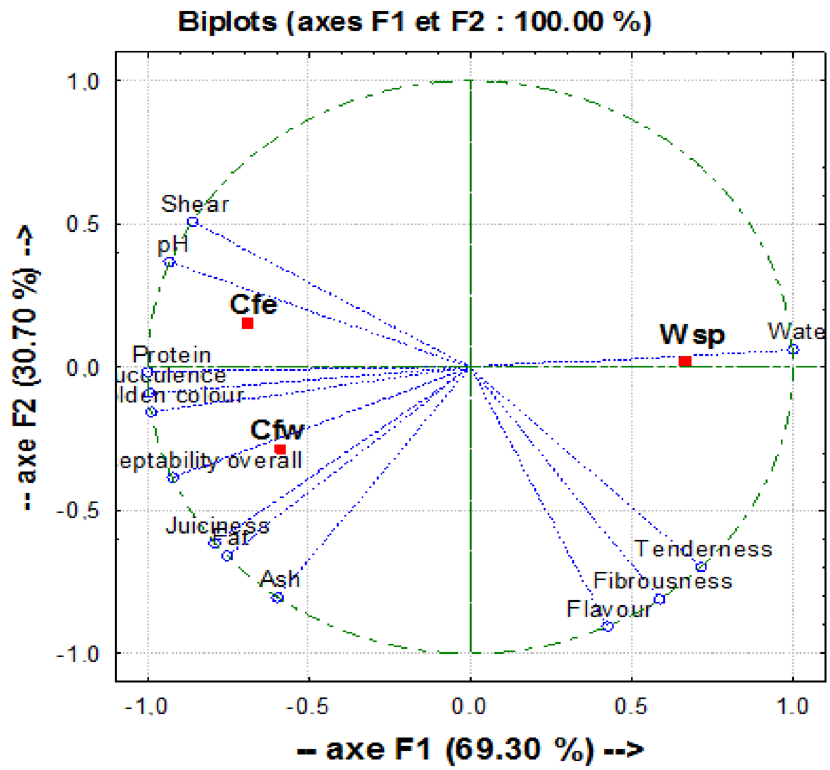

Figure 4. Principal component analysis loading plot showing the correlation of physicochemical parameters and sensory attributes of meat from rabbits fed with a commercial feed (Cfe), a commercial feed + water spinach (*Ipomoea aquatica*) (Cfw) and a feed composed only of water spinach (Wsp) respectively.

accepted (score of overall acceptability > 5). The fact that meat of rabbit fed with the Cfw had the highest score (7.2) could be linked to the physicochemical characteristics of the same rabbit meat. However, no significant difference was observed for the golden colour of the meat from the rabbits fed with the three diets whereas meat colour is one of the most important characteristics used by consumers when purchasing meat. Therefore, meat appearance influences consumer's acceptance of the meat. We recorded that the meat produced from different diets varies for taste and fibrousness. Thus, the criteria the succulence, the juiciness and the tenderness had given more influence in rabbit meat quality in this experiment. Consequently, the meat of rabbit fed with Cfw was succulent, juicy and tender due to the supplementation. In fact, during the cooking, we observed that the bone was easily detached from the meat of rabbit fed with water spinach only. This fact could therefore explain the tenderness of this meat. Similarly, the high succulence score in the meat of rabbit fed Cfw could be explained by the minerals contained in the raw materials used for the formulation of the feed, which give extreme succulence to the meat. In addition, low succulence and juiciness recorded for the meat of rabbit fed water spinach could be due to the fact that during the cooking, more water molecules were gone through this meat. Hongbété et al. (2016) recorded three types of rabbit meat accepted by a taste panel but with a predominance of meat of rabbit fed with a mealy food rich in wheat bran, rice and palm kernel cake in terms of tenderness and succulence. The tenderness is considered as important sensory attributes affecting meat acceptability. Caron et al. (1990) explained that juiciness and tenderness were associated with the relative proportions for fat and protein.

Liu et al. (2003) and Volek et al. (2018) reported that the tenderness significantly decreased with age. So, the utilisation of water spinach as forage could resolve this problem. We were surprised that taste panellists had observed a significant diets effect for tenderness, juiciness and succulence but not flavour. A similar finding was reported by Blasco et al. (2018) for rabbit meat and Caron et al. (1990) for Japanese quail meat.

Overview of relationship between physicochemical and sensory attributes

An overview is performed in the form of a principle component analysis (PCA) on physicochemical and sensory attributes (Figure 4). Here, the PCA is resulted in two axes accounting for 100% of the total variation, of

Table 6. Correlation coefficients between sensory characteristics and physicochemical qualities.

	Golden colour	Tenderness	Succulence	Juiciness	Flavour	Fibrousness	Acceptability overall	Water	Protein	Fat	Ash	pH	Shear
Golden colour	1	-0.595	**0.998**	0.878	-0.277	-0.451	0.972	-0.995	0.990	0.848	0.717	0.860	0.770
Tenderness		1	-0.650	-0.138	0.937	0.986	-0.392	0.670	-0.703	-0.078	0.133	-0.922	-0.971
Succulence			1	0.842	-0.344	-0.512	0.954	**-1.000**	**0.997**	0.809	0.667	0.894	0.813
Juiciness				1	0.217	0.032	0.965	-0.828	0.801	**0.998**	0.963	0.511	0.371
Flavour					1	0.983	-0.046	0.368	-0.410	0.275	0.471	-0.729	-0.826
Fibrousness						1	-0.230	0.534	-0.572	0.092	0.299	-0.843	-0.916
Acceptability overall							1	-0.946	0.930	0.948	0.860	0.718	0.600
Water								1	**-0.999**	-0.793	-0.647	-0.905	-0.828
Protein									1	0.764	0.612	0.924	0.853
Fat										1	0.978	0.458	0.315
Ash											1	0.261	0.108
pH												1	0.988
Shear													1

In bold, significant values (excluding diagonal) at $P < 0.05$

which 69.30% was explained by the first axis (axis F1) and 30.70% by the second (axis F2). About the first axis, the Wsp, water spinach, used to fed rabbit were located at the right hand part of the Figure 4, where the meat samples of rabbit fed with Wsp have the highest moisture content, fibrousness and tenderness. It appeared that water spinach used only as feed affects meat quality, whether physicochemical or organoleptic. This suggested that meat sample of rabbit fed with Wsp contained more water due to the fact that water spinach might be considered as a potential source of feed protein concentrate. Samkol (2009) reported that water spinach foliage contained a high source of protein and lower fibre as a supplement to concentrates for rabbits and supported higher live weight gain and lower feed cost, compared with other vegetable leaves. About the second axis, the Cfe (commercial feed) and Cfw (commercial feed+water spinach), used to fed rabbit largely located in the left hand part of the Figure 4, have the highest contents of protein, fat, pH, shear force and the highest Juiciness, succulence and more acceptable. This suggested that the nutritive values of rabbit meat are powerfully correlated with the chemical composition of the animal diets raw materials.

The succulence of meat samples was significantly ($P < 0.05$) and positively correlated with golden colour ($r = 0.99$) and with protein ($r = 0.99$) and strongly negatively with moisture content ($r = -1$) (Table 6). These correlations indicate that meat cooking process involved Maillard's reaction, thermal degradation of proteins (amino acids), is crucial in generating meat golden colour and succulence with no more water content. During cooking, more water in meat, accompanied by water loss, could alter the state of being sweet and delicious of the meat. The juiciness of meat samples was significantly and positively correlated with fat ($P < 0.05$, $r = 0.99$). The juiciness is defined as a combination of water and the melted fat constituted a broth which when returned in the meat is released upon chewing. So high fat in meat of rabbits fed with Cfw could explain this preference due to the fact the juiciness of meat is important for consumer choice is related to fat content.

Conclusion

The experiment has shown that Cfw and Wsp feed induced the best performance compared to Cfe feed. In addition, it has shown that it would be better to use water spinach (*I. aquatica*) as supplement for rabbit diet to have tenderer, juicy and succulent rabbit meat. Therefore, this study is a contribution to promote local forage species as water spinach for rabbit feeding to increase daily weight gain of rabbits and meat sensory properties of rabbits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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SUPPLEMENTARY MATERIAL

Table S1. Physicochemical data.

	Diets	Moisture	Protein	Fat	Ash	pH	Shear force (N)
1	Cfe	70.50	19.31	4.31	1.24	5.87	1.09
2	Cfe	71.60	19.45	4.24	1.01	5.86	1.12
3	Cfe	73.40	18.95	4.2	1.01	5.86	1.08
4	Cfe	73.30	19.35	3.98	0.858	5.8	1.09
5	Cfe	72.60	19.21	4.45	0.98	5.86	1.05
6	Cfe	72.40	19.46	4.84	1.004	5.86	1
7	Cfw	68.70	19.47	4.8	1.89	5.82	0.78
8	Cfw	69.94	19.56	4.89	1.08	5.82	0.65
9	Cfw	69.92	20.87	6.94	1.04	5.81	0.82
10	Cfw	74.06	19.36	6.45	1.25	5.83	0.68
11	Cfw	74.80	20.15	5.52	1.45	5.83	0.81
12	Cfw	71.20	20.19	5.84	1.47	5.84	0.91
13	Wsp	79.30	18.34	3.23	1.025	5.77	0.31
14	Wsp	77.20	18.45	3.015	1.045	5.76	0.32
15	Wsp	77.10	17.45	2.65	1.2	5.77	0.36
16	Wsp	77.75	16.2	2.51	0.93	5.76	0.37
17	Wsp	74.60	17	5.9	0.84	5.75	0.39
18	Wsp	75.60	17.32	5.87	0.98	5.76	0.59

Cfe: Commercial feed; Cfw: Commercial feed + water spinach; Wsp: Feed composed only of water spinach.

Table S2. Sensory data.

N°	Carcass	Dory colour	Tenderness	Succulence	Juiciness	Fibrousness	Flavour	Over all acceptability
1	Cfe	5	6	7	5	4	6	6
2	Cfe	5	5	8	5	5	5	6
3	Cfe	5	7	7	7	4	6	6
4	Cfe	5	5	6	6	6	7	6
5	Cfe	6	4	6	4	5	6	5
6	Cfe	5	6	7	5	4	7	7
7	Cfe	5	5	7	6	5	6	7
8	Cfe	5	7	8	5	4	5	8
9	Cfe	6	6	6	6	5	7	5
10	Cfe	6	6	7	5	5	6	6
11	Cfe	5	7	7	6	5	5	7
12	Cfe	5	6	6	5	4	7	6
13	Cfe	5	6	6	5	4	5	6
14	Cfe	6	7	8	4	5	6	7
15	Cfe	6	6	7	5	6	5	5
16	Cfe	5	6	7	5	4	6	7
17	Cfe	5	5	6	6	4	6	5
18	Cfe	6	6	6	5	4	6	6
19	Cfe	7	4	8	6	5	7	7
20	Cfe	5	6	8	5	5	6	7
21	Cfe	6	8	7	6	4	5	7
22	Cfe	5	7	7	5	5	6	5
23	Cfe	5	6	8	6	5	5	7
24	Cfe	7	6	8	7	6	6	6

Table S2. Sensory data Cont.

25	Cfe	5	5	7	5	5	7	6
26	Cfe	6	6	8	5	5	7	7
27	Cfe	5	6	7	6	6	6	5
28	Cfe	6	7	7	4	4	7	7
29	Cfe	5	8	6	5	5	6	7
30	Cfe	4	6	8	5	6	5	6
1	Cfw	6	7	5	6	5	6	6
2	Cfw	5	6	7	6	5	7	7
3	Cfw	6	7	7	6	6	5	7
4	Cfw	5	8	8	6	6	5	8
5	Cfw	6	7	7	7	7	7	7
6	Cfw	5	8	8	7	5	5	8
7	Cfw	6	7	8	6	6	7	8
8	Cfw	5	7	9	7	7	5	8
9	Cfw	6	6	7	6	7	7	6
10	Cfw	6	7	7	6	6	6	7
11	Cfw	6	7	7	6	5	6	7
12	Cfw	5	7	8	6	6	7	8
13	Cfw	7	7	7	7	6	6	7
14	Cfw	5	6	8	7	5	7	7
15	Cfw	5	6	7	7	7	5	6
16	Cfw	6	8	9	8	7	6	8
17	Cfw	5	7	7	6	6	7	7
18	Cfw	6	6	7	6	7	5	6
19	Cfw	5	8	9	6	6	5	8
20	Cfw	5	7	8	7	7	7	8
21	Cfw	5	8	8	7	7	5	8
22	Cfw	5	8	8	7	7	7	8
23	Cfw	5	7	8	6	6	6	7
24	Cfw	6	7	7	8	8	7	7
25	Cfw	5	7	7	7	7	7	7
26	Cfw	6	6	7	6	6	7	6
27	Cfw	4	8	8	7	7	5	8
28	Cfw	5	8	8	7	7	7	8
29	Cfw	6	7	6	6	6	6	7
30	Cfw	5	7	7	6	6	7	7
1	Wsp	5	7	5	4	6	6	6
2	Wsp	5	8	6	5	7	7	6
3	Wsp	4	7	5	5	6	5	5
4	Wsp	5	9	4	5	7	5	5
5	Wsp	5	8	5	5	5	6	4
6	Wsp	5	8	6	5	8	7	5
7	Wsp	4	7	5	5	7	6	5
8	Wsp	4	9	4	4	6	6	4
9	Wsp	5	8	5	3	7	6	6
10	Wsp	5	7	4	5	6	5	5
11	Wsp	5	9	6	6	7	6	5
12	Wsp	5	7	7	5	6	6	5
13	Wsp	6	9	5	4	7	7	4
14	Wsp	6	8	4	5	7	6	5
15	Wsp	5	6	5	5	7	6	6
16	Wsp	7	8	6	3	6	6	5

Table S2. Sensory data Cont.

17	Wsp	6	8	6	5	7	7	5
18	Wsp	5	7	5	4	6	6	4
19	Wsp	5	7	4	5	6	6	6
20	Wsp	7	8	4	6	7	7	5
21	Wsp	5	8	5	5	8	7	6
22	Wsp	7	7	5	4	6	6	5
23	Wsp	5	7	5	5	6	6	6
24	Wsp	6	7	6	5	7	7	5
25	Wsp	5	9	5	5	8	7	5
26	Wsp	5	7	6	6	6	6	5
27	Wsp	5	7	5	5	7	7	6
28	Wsp	7	8	4	5	6	5	5
29	Wsp	5	7	5	5	8	6	5
30	Wsp	5	7	6	5	7	6	5

Cfe: Commercial feed; Cfw: Commercial feed + water spinach; Wsp: Feed composed only of water spinach.