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Technological, Sensorial and Nutritional Meat Quality Traits from Pig Fed with Conventional and Unconventional Diets

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Abstract

The aim of the study was to evaluate the impact of unconventional food resources on the quality of pig meat. 90 pigs of which 20 were slaughtered at 180 days old for meat quality evaluation. It came out from the study that the highest L* and b* were obtained in A0 commercial feed, while the highest a* was recorded in A3 ($P < 0.05$). From 45 minutes to 24 h post-mortem, the highest pork hue value was recorded in A2, whereas the highest chromaticity was found in A0. The pH 45 and pH 24 of Mld (Muscle *Longissimus dorsi*) were lower in control group than in experimental groups. The cooking loss and water-holding capacity of the meat from A4 were higher than those of other treatments. Luminance, redness, yellowness, chroma values and pH of the pork had increased during the post-mortem aging time for the both diet treatments while the hue value decreased ($P < 0.05$). Nutritionally, the protein content, the fat content, the dry matter content and the ash content varied respectively from 24.45% to 26.87%, 0.52% to 1.6%, 26% to 27.5% and 1.1% to 1.79% with the highest protein contents found in meat from unconventional feed A4 ($P < 0.01$) while the highest fat content (1.6%) was obtained from meat of the control group A0 ($P < 0.001$). The texture of the meat from the control group was better than those of experimental groups ($P < 0.01$). Overall, unconventional diet based on Azolla and Moringa improves technological and nutritional pork quality.

Keywords

Pig, Meat Quality, Unconventional Diet, Benin

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1. Introduction

Meat is an important foodstuff and one of the most expensive components of human nutrition [1]. Meat provides valuable amounts of protein, fatty acids, vitamin, minerals and other bioactive compounds. Indeed, a variety of meat is eaten in order to get balanced diets and more appetite. According to the three important aspects such as nutrition sensorial and beliefs that are required to be improved [2], people can prefer chicken, beef and pork. The meat derived from hunting is appreciable by others, although consumers are highly interested in the quality of the products they eat, especially when this refers to meat [3]. FAO (2014) [4] claimed that pig meat consumption had severely increased and at the same time established a growth of consumer preferences to satisfy the tastes of the refined meat and to ensure a healthy and balanced nutrition due to its good quality. This has desirable implications on enterprise profit as feed constitutes a large portion (60% - 70%) of pig enterprise costs [5], [6]. Thus, pig presents some characteristics that are positive for profitability: high growth rate and interesting food conversion ratio [7]. The value of a meat animal is realised when its product is marketed and expressed relative to the input costs incurred [8]. According to Lee *et al.* [9], the surface exudate expressed as water holding capacity or drip loss, the ultimate pH (pH 24) and the colour are the three important parameters to find out more about the quality of pork. By this predictors, meat can be classified into quality categories such as PSE (pale. soft. exudative), normal or RFN (red. firm. non-exudative) and DFD (dark, firm, and dry) meat. Beside these traditional categories, Tomovic *et al.* [10] have also reported RSE (reddish-pink. soft. exudative) and PFN (pale, firm and non-exudative) defects in pork. The aim of this work is to compare the meat quality from conventional and unconventional commercial feeds in pig.

2. Materials and Methods

2.1. Area of Study

The study was conducted at the experimental farm of the Agronomic Science Faculty of the University of Abomey-Calavi located in Abomey-Calavi in Atlantic Department. Situated at latitude of 6˚27' North and at a longitude of 2˚21' East, the Commune of Abomey-Calavi covers an area of 650 km^2 with a population of 307,745 inhabitants [11]. This area exhibits climatic conditions of sub-equatorial type, characterized by two rainy seasons with an uneven spatial and temporal distribution of rainfall: major (from April to July) and minor (from September to November). These two seasons are separated by a dry season. Average rainfall is close to 1200 mm per year. The monthly average temperatures vary between 27˚C and 31˚C and the relative air humidity fluctuates between 65%, from January to March, and 97%, from June to July.

2.2. Methodology

2.2.1. Animal

A total of 90 pigs were divided in 5 groups constituted and used for the study. The first group was fed with a conventional commercial feed (A0). The four following groups were respectively fed with four different unconventional feeds (A1, A2, A3 and A4) containing Azolla, Moringa, rice bran, and different rates of chicken and fish viscera (**Table 1**).

The pigs were fed with wet diets. After the study completion at 90 days, four pigs from each group were selected for the evaluation meat quality. The traits of meat quality were examined in *Longissimus dorsi*.

2.2.2. Technological Quality

The pH was recorded at 45 minutes and 24 hours post mortem using a portable pH-meter HANNA. Drip loss was determined by the method used by Tougan *et al*. [12] after cooling for 24 h at 4˚C. Cooking loss was determined by placing weight samples of *L. dorsi* in polythene bags and heating then in a water bath at 70˚C for 50 min. The samples were then weighed and cooking loss was calculated as a percentage of weight of the original samples.

The colour of the meat was measured a slaughtering day and 24 hours post mortem with a Minolta Chromameter CR400 (Minolta Corporation, Ramsey, NJ, USA) after exposing the surface to the air for 1H 30 min at 4˚C. The average of triplicate measurements was recorded and the results were expressed as C.I.E (Commission Internationale de l'Eclairage) L*, a* and b*. The parameters L*, a* and b* represent lightness, redness and yellowness. From the a* and b* values, the hue (Hab) and the chroma (Cab) values were calculated. Hue, namely

Table 1. Composition of the different diets.

	Control diet	Experimental diets			
Foodstuffs (%)	A0	A1	A2	A3	A4
Maize	29	-	-	-	-
Wheat bran	24.65	-	-	-	-
Palm kernel cake	32.5	-	-	-	-
Cotton seed cake	5	-	-	-	-
Fish meal	5	-	-	-	-
Shell	1.5	-	-	-	-
C5	1.5	-	-	-	-
Phosphate	0.5	-	-	-	-
Sulfate	0.05	-	-	-	-
Salt	0.3	-	-	-	-
Azolla meal	-	40	40	40	40
Moringa meal	-	25	25	25	25
Rice bran	-	30	30	30	30
Chicken viscera	-	0	1.5	3.5	5
Fish viscera	-	5	3.5	1.5	0
Total	100	100	100	100	100

the observable colour (e.g. red, blue, yellow), is an angular measurement calculated by the following equation: Hab = $\tan^{-1}(b^*/a^*)$ [13]. Chroma is an expression of saturation or intensity of the colour attained and is expressed by the equation: Cab = (a × 2 + b × 2)1/2 [13].

2.2.3. Sensory Quality

Sensory analysis was performed on each dietary treatment with a panel of jury members from 12 randomly selected potential consumers. For the tasting, two groups of identical samples of 50 g of *Longissimus dorsi* muscle cuts were used. These pieces were boiled with water in a pot without seasoning and salt for 1 hour at 75˚C. After cooling to room temperature, the samples of cooked meat were cut into small identical cubes. Each judge received in a different colour trim a portion of each cutting counterpart belonging to each dietary treatment and completed a form of summary of the results of the tasting. Three repetitions were made for each cut dietary treatment. The judges evaluated the three important sensory characteristics of meat (tenderness, juiciness and flavour). These characteristics were rated on scales of 1 to 5. For tenderness, the scores 1, 2, 3, 4, and 5 correspond respectively to very hard, hard, acceptable, tender and very tender. As for juiciness, the scores 1, 2, 3, 4, and 5 correspond respectively very dry, dry, acceptable, soft and very soft. The intensity of flavour can obtain the score very low (1), low (2), acceptable (3), strong (4) and very strong (5).

2.2.4. Chemical Composition

The chemical composition was determined according to the standards used by Tougan *et al.* [14]. Moisture content was determined gravimetrically by drying 6 g of meat at 105˚C accordingly to the NF V 04 - 401 French standards method. Each value was an average of 2 measurements. Crude protein was determined by Kjeldahl method according to the NF V 04 - 407 norm and using a Kjeltec Auto Sampler System 1035 Analyzer (Foss, Benelux). Each analysis was repeated twice. The total ash content was determined according to the NF V 04 - 404 French standard method. About 6 g of samples were ashed in an oven maintained at 550˚C to determine ash content and was repeated twice. The fat content was determined by Soxhlet method according to the NF V 04 - 402 standard ISO 1443:1973. Each analysis was repeated twice using petroleum ether at 40˚C - 60˚C.

2.3. Statistical Analysis

The data collected on the meat quality traits of the different group were analysed with the software SAS (Statistical Analysis System, 2006). For the analysis of variance, a fixed effects linear model was adjusted to the data and includes the fixed effects of the diet and *post mortem* aging time. The F test was used to determine the significance level of each effect in the model. Means were compared two by two by the Student's t test.

3. Results

3.1. Technological Quality of Meat

The variation of technological quality of meat according to the diet and the *post mortem* (PM) aging time are given in **Table 2**. The highest luminance and yellow index were obtained in A0 commercial feed, while the highest redness was recorded in the treatment A3 ($P < 0.05$). From 45 minutes PM to 24 h post-mortem the hue was raised at the feed A2, whereas a higher chromaticity was noticed with the feed A0.

The pH values ranged from 5.54 to 5.38 for the control feed A0 but varied from 5.7 to 6.64 for the meat obtained from unconventional feeds. During the experiment, pH 45 (recorded at 45 minutes PM) and pH 24 (recorded at 24 hours PM) in the muscle *Longissimus dorsi* were lower in control group than in experimental groups. The pH values were significantly different among all of the five treatments ($P < 0.05$). The pH drop was rapid in the group fed with unconventional feeds.

The cooking loss and water-holding capacity of the meat from the treatment A4 were higher than those of other treatments. The loss of juices during cooking and water holding capacity were significantly different ($P < 0.05$), whereas no difference was observed for the drip loss ($P > 0.05$). The highest value of cooking loss (24.24%) was observed in meat from unconventional feed A3, while the higher drip loss (3.05%) was recorded in meat from the feed A4. Water holding capacity was of 22.85 for unconventional feeds to 20.5% for the control feed A0.

Luminance, redness, yellowness, chroma values and pH of the pork had increased during the post-mortem aging time (from 45 minutes to 24 hours) for the both diet treatments while the hue value decreased ($P < 0.05$).

Table 2. Effect of diet (A0, A1, A2, A3 and A4) and post-mortem aging time on pork technological quality.

Variables	Day	A0		A1		A2		A3		A4		Diet	Effect of PM aging time
		Mean	ES	Mean	ES	Mean	ES	Mean	ES	Mean	ES	effect	
L*	J0	51.5	4	50.1	3.5	48.9	3.5	48.6	3.5	48.6	3.6	NS	NS
	J1	52.7	2.6	52.2	2.4	52.7	5.3	52.3	2.4	51.5	3.3	NS	
a*	J0	9.5	2.3	8.7	3.4	7	2.5	9.8	2.2	8.2	2.2	***	*
	J1	11.3	2	9.7	2.5	8.8	1.8	11.5	2.5	10.8	2.1	***	
b*	J0	8.6	3.2	6.5	2.5	6	1.7	7.9	2.5	6.7	1.9	***	*
	J1	11.5	1.4	9.6	2	10.2	1.7	11.1	2.2	10.8	2	***	
Hue H*	J0	0.2	0.03	0.17	0.04	0.21	0.05	0.15	0.03	0.18	0.03	***	*
	J1	0.2	0.02	0.16	0.04	0.17	0.04	0.14	0.03	0.14	0.02	***	
Chroma C*	J0	12.9	3.6	10.9	4.02	9.3	2.8	12.6	3.1	10.7	2.6	***	*
	J1	16.1	2.2	13.7	3	13.5	2.3	16	3.	15.4	2.7	***	
pH	J0	5.5	0.5	6.6	0.5	5.8	0.6	6.7	0.3	6.5	0.4	***	*
	J1	5.4	0.2	5.9	0.2	5.6	0.3	5.7	0.24	5.6	0.3	***	
Cooking loss		18.5	5.4	18	2.8	19.7	7.6	24.2	3.4	19.8	6	***	*
Drip loss		2	0.8	2.2	1.3	2.3	1.9	2.2	1.2	3.05	1.5	NS	*
WHC		20.5	3.2	20.1	3.2	22.03	3.2	26.5	3.2	22.8	3.2	***	*

WHC: Water-holding capacity. SE: Standard error.

3.2. Nutritional and Sensorial Quality of Meat

Nutritionally, the protein content, the fat content, the dry matter content and the ash content varied respectively from 24.45% to 26.87%, 0.52% to 1.6%, 26% to 27.5% and 1.1% to 1.79% (**Table 3**).

The highest protein contents were found in meat from unconventional feed A4 ($P < 0.01$) while the highest fat content (1.6%) was obtained from meat of the control group A0 ($P < 0.001$). Ash content was more important in meat from the unconventional fed A4 ($P < 0.01$). However, the meat the control group contained more dry matter than those of the experimental groups ($P < 0.01$).

For the sensory quality of the meat, no difference was found between flavor and juiciness of meat from control and experimental groups ($P > 0.05$). However, the texture of the meat from the control group was higher than those of the meat from experimental groups ($P < 0.01$) (**Table 4**).

4. Discussion

4.1. Variation of Meat Technological Quality

There are many factors which affect the quality of pig meat such as genetics associated factors, nutrition, rearing conditions, handling of animals during loading into vehicles, transportation, depot, stunning, slaughtering and cooling of the carcass [15]. The results found herein indicate that there are many differences in post mortem metabolic rate and meat quality according to the post mortem aging time and diets. In the current study, the ultimate pH of meat is related to several meat quality aspects including L* value and water losses. In agreement with no treatment effects on the pH of meat, no significant effects of treatment were observed on L* value or on drip and cooking losses in the current study. The redness (a*) of meat is greatly influenced by the meat concentration in pigment [16] and by the pH of the meat because oxidation and reduction processes of myoglobin are pH-dependent [17]. According to the current results, the pH value recorded at 45 minutes *post-mortem* in Mld was lower in control group. It was found that meat of pigs was influenced by the feed quality. These results confirm the finding of De Smet *et al.* [18] who indicate that meat quality depends highly on the diets.

High fibre in unconventional diets may inhibit the availability of iron which can limit pigment formation [17]. Water-holding capacity is an important technological parameter of meat quality. It was different among investigated pig group in our study. According to Hocquette *et al.* (2005) [19], the water holding capacity influences juiciness of the meat. In the current study, the water holding capacity is higher in pigs fed unconventional diet with relatively higher juiciness. According to Clinquart *et al.* [20], meat with good water holding capacity helps

Table 3. Effect of diet (A0, A1, A2, A3 and A4) on the nutritional value of pork.

Attributes	A0	A1	A2	A3	A4	RSD	ANOVA
Protein (g/100 g)	24.5a	24.5a	25.2b	25.9c	26.8d	0.7	**
Fat (g/100 g)	1.6a	0.5b	0.5b	0.7c	1d	0.5	***
Dry matter (g/100 g)	27.5a	27.3a	26b	27.4a	27.3a	0.8	**
Ash (g/100 g)	1a	1.3b	1.5c	1.6cd	1.8d	0.4	**

**: $P < 0.01$; ***: $P < 0.001$. The means of the same line followed by different letters differ significantly with the threshold of 5%. RSD: Residual standard deviation.

Table 4. Effect of diet (A0, A1, A2, A3 and A4) on pork sensory quality.

Variables	A0		A1		A2		A3		A4		ANOVA
	Mean	ES	Mean	ES	Mean	ES	Mean	ES	Mean	ES	
Flavour	2.7	0.8	2.2	1.1	2.3	0.7	2.5	1.3	2.5	1.08	NS
Juiciness	2.8	0.7	2.6	0.9	2.9	0.9	3.1	0.8	3.1	0.8	NS
Texture	2.5	0.9	1.3b	0.5	2.1	0.8	3.1a	1.08	3.1a	0.8	*

*: $P < 0.05$; NS: Non-significant. The means of the same line followed by different letters differ significantly with the threshold of 5%.

to limit weight losses during its conservation and its transformation into cooked products. Therefore, it could be concluded that the unconventional feeds used in the current study improve technological properties in pig meat of Benin. The values of WHC found herein are below those found by Jukna and Jukna [21] and twice higher than the value reported by Kusec *et al.* [22] on the Pietrain and Large White pigs. The conditions of slaughter and post-slaughter being identical in this study, the water retention capacity differences may be related to the feed composition and its impact on muscle characteristics.

4.2. Variation of Meat Nutritional Quality

The nutritional value of pork found herein is better compared to the value reported by Rybarczyk *et al.* [23] on the Pietrain pig meat quality and other crossbred pigs with Pietrain. Similarly, the meat protein content recorded in the current study is higher than the results of Jukna and Jukna [21] and Rybarczyk *et al.* [23].

The protein and fat contents of pork derived from unconventional feed used in this study are better than those of pigs fed with the conventional diet. In addition the technological quality of the meat was not affected by the type of the diet. Therefore, it is possible to get good quality of pork by feeding the animals with unconventional local resources.

Research carried out in recent years emphasized that for consumers the sensory quality of culinary meat, which is determined mainly by level of intramuscular fat and other traits such as drip loss and the pH of the meat, is very important. The pH has a high influence on water holding capacity (WHC), which is closely related to product yield and pork quality [20]. WHC is the ability of meat to retain its water during processing, storage and cooking. Low WHC often results in high drip loss and poor eating quality (dryer and tougher in the cooked state). Water loss means a loss of saleable product yield. The values of pH, drip loss, cooking loss, colour (L*, a*, b*) are within the values reported in literature [24]-[26].

The level of intramuscular fat depends on breed, portion of meat in the carcass, slaughter weight and nutrition of the animal during the growing period [27]. Recent studies highlighted the link between these properties and the level of intramuscular fat in meat and marbling. These two traits vary according to breed and environmental conditions. Fat content in muscle tissue influences meat quality significantly, particularly tenderness, juiciness and flavour of meat, and drip loss. Recent studies on crosses between Naïma sows and boars suggested the existence of an intramuscular fat gene in animals where high levels and a high degree of variability of intramuscular fat were observed [28] [29].

Concerning the implications of the feeding regime for pork quality traits, the results conclusively confirmed the results of Sundrum *et al*. [30], during their study on the effects of feeding strategies, genotypes, sex, and birth weight on carcass and meat quality traits under organic pig production conditions. They found that lean meat percentage and meat area of the muscle *Longissimus dorsi* (Mld) and the meat: fat ratio were markedly lower with feeding regime growing and finishing phase than with the regimes finishing and control diet ($p < 0.05$), whereas the fat area was not affected. Due to the large variation in drip losses after 24 h, differences between feeding regimes were not statistically significant ($p > 0.05$). In contrast, intramuscular fat content of the Mld in their study clearly increased with feeding regime growing and finishing compared with the control diet from 1.22% to 2.80% ($p < 0.05$).

In studies of Essén-Gustavsson [31], muscle fibre composition and the oxidative and glycolytic capacity did not differ between the pigs given a low- and a high-protein diet whereas the low-protein diet caused a higher intramuscular fat content than the pigs fed a high-protein diet. Intramuscular fat values correlated with triglyceride content in the muscle, which in turn was negatively related to mean fibre area. Larzul *et al.* [32] did not find any relationship between intramuscular fat content and the numerical percentage of fibre types at a commercial slaughter weight of purebred Large White pigs.

The protein contents of pork found herein are higher than those obtained by Sundrum *et al*. [30], while the intramuscular fat contents recorded in our study are lower than the values reported by Sundrum *et al*. [30] in four different genotypes: Pietrain × (German Landrace × Large White), Duroc crossed with a strain of German Landrace, Pietrain × German Swabian Hall, and purebred German Swabian Hall breed.

5. Conclusion

Analysing the pig meat from unconventional and conventional feed, it can be concluded that unconventional meat is healthier with higher protein content and lower fat content. The feeding regime was the main source of variation for intramuscular fat content in the *Longissimus dorsi* muscle. Unconventional diet based on Azolla and Moringa can improve technological and nutritional pork quality.

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