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ABSTRACT This study is part of a series of studies on the possibility of substituting alternative protein source supplements to the diet of guinea fowl in order to improve food security in the fight against poverty on the African Continent. This study assesses the identified sensory characteristics of guinea fowl meat and consumer preferences to determine if the possible alternative supplements identified result in a product acceptable to consumers and if consumer preference was evident. Indigenous guinea fowl or selected breed (Galor animals) were fed a control diet C, a commercial diet I (diet used for guinea fowl in Côte d'Ivoire), or one of 2 experimental diets N (diet C supplemented with 15% cashew nut meal) or diet H (diet C supplemented with 15% detoxified hevea seed meal). Meat samples were assessed by 120-trained people using 18 sensory attributes. Principal component analysis (**PCA**) showed that meats from guinea fowl fed diet C or diet I were clearly distinguished from guinea fowl fed N or H diets and that meat of indigenous guinea fowl or Galor animals were also clearly distinguished. The results of the hierarchical group analysis showed that meat from guinea fowl fed diet H was the preferred guinea fowl meat. A first partial least squares regression PLSR1 identified the relationships between guinea fowl meat samples, their sensory attributes and consumer preference and showed that 82.6% of the sensory data of the first 2 principal components accounted for 95.5% of the preference. The PLSR2 identified the relationships between guinea fowl samples, their sensory attributes, and their biochemical characteristics and showed that the fat content of the meat determined the intensity of flavor, odor, juiciness, and tenderness of the meat. Our results showed that meat from birds fed diet H was preferred, and thus emphasized the existence of a place for the use of hevea seed meal in guinea fowl diet in Côte d'Ivoire.

Key words: guinea fowl, hevea seed, cashew nut, meat, sensory attributes

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INTRODUCTION

Food security and poverty are the major concerns in Africa. Poultry production represents a good opportunity in poverty alleviation important in the fight against poverty and the improvement of the living conditions of rural African households. Among poultry enterprises, guinea fowl (**GF**) production, under traditional African rearing systems, is generally practiced by small-scale farmers experiencing poverty. However, the need for this type of GF production to be sustainable is increasing in developing countries, like Côte d'Ivoire, where the population growth is high with an increasing demand for meat from poultry such as GF (Koné et al., 2018; Kouassi et al., 2019). GF production for meat can be economically advantageous in many parts of the world (Nahashon et al., 2006). However, profitability remains a challenge in the face of increasing feeding cost. On the market, increased prices of feed ingredients such as corn and soybean justify the inclusion of less-conventional feed ingredients when possible (Laudadio et al., 2012). This study follows-on from the earlier study which identified that detoxified hevea seed meal and cashew nut meal, readily available at a low cost, are suitable as a substitute protein supplement, in place of soybean for the diet of guinea fowl (Koné et al., 2020). Indeed, detoxified hevea seed meal is already considered a potential diet ingredient in pigs (Madubuike et al., 2006; Koné et al., 2016), guinea fowl (Koné et al., 2020; Kouassi et al., 2020), and cockerels (Ravindran et al., 1987). Cashew nut meal has also been used in pig diets

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(Koné et al., 2016). The study presented here set out to identify the sensory characteristics and consumer preferences of guinea fowl meat produced using these alternative protein supplements. To our knowledge, within an African context, this is the first assessment and analysis of the sensory characteristics and consumer preferences for guinea fowl meat and is conducted with the following objectives: 1) to determine the effect of hevea seed meal or cashew nut meal supplemented diets on the sensory characteristics and consumer preference for guinea fowl meat of 2 origins (indigenous breed and ameliorated breed Galor), and 2) to highlight the relationship between the descriptive sensorial attributes and chemical characteristics of the guinea fowl meat.

MATERIALS AND METHODS

Experimental Site Situation, Guinea Fowl, and Treatments

The animals used were reared and slaughtered in compliance with regulations for the humane care and use of animals in research, according to EU directive 86/6096. (National Authorization to Experiment on alive animals n°3502 delivered to M. Kouba by the French Minister of Agriculture).

The study was carried out in Côte d'Ivoire, at the National Polytechnic Institute Félix Houphouët-Boigny of Yamoussoukro (INP-HB), in collaboration with National Institute of Agronomic and Environmental Research (INRAE), France. The meat samples assessed came from 16-wk-old female guinea fowl from indigenous or selected breed (Galor animals). Two hundred guinea fowl from each breed were divided into 4 groups that is, four groups of 50 birds in total for each breed. After a 4-wk rearing period on a basal starter diet, birds of each group were randomly assigned to pens, with 10 birds per pen, where they remained for the following 12 wk, that is, to 16 wk of age. Guinea fowl of each breed received each of the 4 grower diets (5 replicates of ten birds of each breed for each diet). The guinea fowl of each breed were fed randomly either:

(i) commercial **diet I** (Ivograin, used for all the poultry in Côte d'Ivoire), or

(ii) control **diet C** or

(iii) trial **diet N** (diet C supplemented with 15% cashew nut (*Anacardium occidentale*) meal) or

(iv) trial **diet H** (diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal).

Diets C, N, H were formulated to be isoproteic (respectively 22.4, 22.2, 22.1%) and isoenergetic (respectively ME of 12.2., 13.1, 12.5 MJ/kg feed).

At the end of the experiment (16 wk old), after 12 h of fasting, the animals were electrically stunned, and exsanguinated. The carcasses were eviscerated and cut according to the method described by Koné et al. (2020) into 4 pieces (breast [including bone and the 2 pectoral muscles], the whole thighs and the wings). Detailed information on diet composition and results with regard to bird slaughter performance were reported earlier (Koné et al., 2020). They are provided in this manuscript as respectively in Tables 1 and 2.

Chemical Analyses

Samples of thigh muscle (Quadriceps femoris) were collected from ten birds per pen (50 animals per dietary treatment per breed) and analyzed for dry matter, ash and Crude Protein (N × 6.25) content, according to AOAC (2006). The water content was determined according to AOAC 950.46. Samples were dried in the oven at 105°C. The ash content was determined by mineralization of samples at 550°C according to AOAC 920.153. Total protein (crude protein, N 6.25) content was assessed by the Kjeldahl method according to AOAC 928.08. Lipids were extracted from samples of

Table 1. Ingredient and chemical composition of diets (Commercial diet (I), control diet with Soya as sole protein supplement (C), trial grower cashew nut seed meal supplemented diet (N), trial grower hevea seed meal supplemented diet (H)).

Diets	I	C	N	H
Ingredients (g/kg)				
Shell	5	3	1	5
Fish flour	105	100	100	100
Maize	610	590.7	547.7	528.7
Wheat middlings	105	120	120	120
Cashew nut seed meal	-	-	150	-
Hevea seed meal	-	-	-	150
Soybean meal	155	182	77	92
Salt	1.5	1.8	1.8	1.8
Choline chloride	1.0	1.0	1.0	1.0
L-Lysine HCL	2.0	2.0	2.0	2.0
DL-methionine	1.6	1.5	1.5	1.5
Theonine	0.4	0.5	0.5	0.5
Dicalcium phosphate	11.2	11	11	11
Vitamin-mineral premix[1]	2.3	2.5	2.5	2.5
Analyses (%)[2]				
Dry matter	90.2	88.5	89.9	89
Crude protein (CP)	21	22.4	22.2	22.1
Lipid	3.6	2.7	3	2.5
Ash	6.7	8	6.7	6.6
Crude fiber	3.6	3.6	3.6	3.3
Fatty acid (FA), % of total FA				
SFA	28.8	27.3	18.9	25.6
MUFA	31.8	28.3	54.7	34.9
PUFA	39.4	44.4	26.4	39.6
n-6	36.9	37.7	23.9	31.2
n-3	2.5	6.7	2.4	8.4
18:2n-6/18:3n-3	16.1	11.4	19.5	4.4
PUFA/ SFA	1.4	1.7	1.4	1.6
Calculations				
ME[3] (in MJ/kg)	12.9	12.2	13.1	12.5
Calcium (%)	1.1	0.9	0.9	0.9
Calcium to Phosphore ratio	1.6	1.2	1.2	1.2

(adapted from Koné et al., 2020).

[1]Supplied per kilogramme of diet = vitamin A 12 500 IU; vitamin D3 2 500 IU; vitamin E 37 mg; vitamin K3 4 mg; vitamin B1 2 mg; vitamin B2 8 mg; vitamin B6 4 mg; vitamin B12 0.04 mg; biotin 0.12 mg; folic acid 2 mg; niacin 37 mg; Co 1.2 mg; Cu 8 mg; Fe 60 mg; I 1 mg; Mn 74 mg; Se 0.6 mg; Zn 75 mg; antioxidant 150 mg; endo-1.4-beta-xylanase 100 U/kg; 6 phytase 1500 U/kg.

[2]Values are the means of 3 analyses per sample.

Table 2. Carcass weight and yield, cuts and abdominal fat proportions of 16-wk-old guinea fowl (Galor or local breeds) fed, from 4-wk of age, different grower diets: grower commercial diet (I), grower control diet with soya supplement (C), trial grower cashew nut seed meal supplemented diet (N), trial grower hevea seed meal supplemented diet (H)).

Parameter	Diet				SEM	Strain		SEM	Probability		
	I [100]	C [100]	N [100]	H [100]		Local [200]	French [200]		Diet	Strain	Diet × Strain
Carcass weight (g)	1054^{a}	950^{b}	789^{c}	942^{b}	23.5	786^{a}	1037^{b}	16.6	$1e^{-03}$	$2.5e^{-06}$	0.5 (NS)
Carcass yield (%)	80.4	79.2	78.6	78.5	0.4	78.6^{a}	79.8^{b}	0.3	0.1	$2.9e^{-02}$	0.2 (NS)
Cuts and tissues (% of carcass weight)											
Breast[1]	32.6	32.3	31.6	31.6	0.3	31.8	32.3	0.2	0.1	0.1	0.9 (NS)
Legs	28.6	28.5	28.8	28.7	0.3	28.8	28.5	0.2	0.9	0.5	0.2 (NS)
Wings	13.6	13.4	14.3	14.1	0.3	13.9	13.8	0.2	0.1	0.7	0.2 (NS)
Abdominal fat	2^{c}	1.5^{b}	1.4^{b}	0.9^{a}	0.1	1.2	1.6	0.1	$3.7e^{-03}$	0.1	0.4 (NS)

(adapted from Koné et al., 2020).
Breast = includes bone and 2 breast muscles.
[] = Number of animals in brackets.
a-cParameter means within rows of diet or breed with no common superscript differ ($P < 0.05$); NS = not significant difference ($P > 0.05$).

muscle, by the chloroform/methanol procedure of Folch et al. (1957).

Guinea Fowl Sample Preparation

In Côte d'Ivoire, poultry thighs are relatively cheap, well adapted to African recipes 'in sauce' and widely consumed. Most thighs consumed in Côte d'Ivoire have been exported from France, where consumers prefer breasts. Thus, we used only thighs (upper part of the leg) for the sensory assessment. Thighs were cooked according to the method described by Sow and Grongnet (2010), under which method panelists could discriminate the taste of 3 types of chicken meat. Ivorians eat and like spicy food, and routinely use the ingredients butter, salt, onion, pepper, and chili; We considered that thigh roasted without at least butter, salt, onion, pepper would not be appreciated by the local consumer panelists (we did not include chili because of its very strong taste). The thighs were coated with butter and seasoned with a mixture of salt (5%), onion (10%), and pepper (5%) before roasting at 160°C for 75 min. The roasted GF thighs (Quadriceps femoris) were then cut into small (2 cm) cubic pieces and placed in plates with covers. The samples were then coded before being submitted to sensory assessors. We will refer to thigh-meat in the manuscript.

Experimental Design of the Sensory Test

Test Room Conditions Due to hot climate in Côte d'Ivoire, we undertook this study in an air-conditioned refectory of the National Polytechnic Institute Félix Houphouët-Boigny of Yamoussoukro. Before each test, we washed and disinfected the refectory. We took care to conduct this assessment during weekends to minimize the influence of noises.

Assessor Selection and Training Human senses are able to identify every type of sensation, but the challenging aspect of using sensory testing is the variability of interpretation using individuals as testing instruments (Bratcher, 2013). Therefore, any study of sensory analysis must begin with training sessions for assessors to generate and select a correct vocabulary to more uniformly describe and rank the product under study. We recruited 120 people to form the panel of assessors, based on their GF meat consumption frequency (at least twice a month) and their sociodemographic characteristics. Panelists were selected from staff members and students from the University of Agronomy (Ecole Supérieure d'Agronomie de Yamoussokro, Côte d'Ivoire), and PhD students from the National Polytechnic Institute Félix Houphouët-Boigny of Yamoussoukro. The final panel comprised 80 men, average age 28 yr, and 40 women average age 25 yr. Panelists were then trained over 3 d for the guinea fowl sensory study. Each session lasted three hours, and focused on the sensory characteristics of guinea fowl meat. Training enabled panelists to identify the sensory attributes required to describe the appearance, odor, flavor, and texture of guinea fowl meat. References and scales were also developed during the training sessions. A final vocabulary was selected and defined and included 3 appearance, 4 odor, 3 flavor, and 8 texture attributes. At the end of the training period, panelists selected 18 sensory attributes to be used for the study. The Likert 5-point psychometric scale was chosen because it is simple and broadly used (Joshi et al., 2015). It was discussed during the training sessions and a comprehensive vocabulary was selected for the guinea fowl meat sensory assessment. The scale ranged from 1 (low expression of the attribute, i.e., not acceptable) to 5 (high expression of the attribute, i.e., excellent).

Sensorial Assessment and Overall Preferences The assessors were assembled for the 2 consecutive days scheduled for the sensory assessments and each was provided with assessment forms, a list of the agreed sensory attributes including definitions and a list of scale credit rankings. The sensory assessments and evaluations were completed over 3 rounds each day, with each assessor receiving 4 samples per round and the same samples in each round, so that each sample, for each of the 4 feed types, was assessed on appearance, odor, flavor, and texture in triplicate for each breed of guinea fowl. Guinea fowl thigh sample presentation was simultaneous for all assessors. Prior to commencement and then between each sample, assessors were asked to cleanse their palate with mineral water (Brand Awa). Each assessor ranked every sample received on each variable from 1 to 5 (1 = not acceptable, 2 = acceptable, 3 = good, 4 = very good, 5 = excellent) according to their level of appreciation, based on the Likert scale discussed during the training sessions and also indicated their overall 'liking' of each sample.

Statistical Analyses

At the end of each session, the completed assessment forms were recovered and the data thereon subsequently recorded, for analysis, using an Excel spreadsheet (Microsoft Corp., Redmond, WA) for the 54,720 individual data items collected in total. The sensory evaluation of the meat was performed comparing hedonic variables of appearance, odor, flavor, and texture recorded using a taste scale ranked from 1 to 5 (1 = not acceptable, 2 = acceptable, 3 = good, 4 = very good, 5 = excellent). The overall liking attribute was also evaluated according to this scale. We performed a separate analysis for this overall liking attribute ranking of our 120 assessors, which for convenience we called "consumer preference". This name will be used throughout the manuscript. Ranking scores mean for each sensory attribute across assessors were calculated to identify the sensory attributes that discriminate between guinea fowl samples, and data were analyzed by the ANOVA option of the generalized linear model (**GLM**) of R 3.4.2 software (Copyright © 2016, R Foundation for Statistical Computing Platform) as a 4×2 factorial arrangement of treatments with diet and breed as main effects.

The statistical model used was $Yijkl = \mu + Di + Sj + (DS)ij + Rijk + \gamma ijkl$, where $Yijkl$ = response variables from each individual replication or pen; μ = the overall mean; Di = the effect of diet; Sj = the effect of breed; $(DS)ij$ = the effect due to interactions between diet and breed; $Rijk$ = the inter-experimental unit (replications) error term, and $\gamma ijkl$ = the intra-experimental unit error term. Two-way interactions between diet and breed were not significant ($P > 0.05$), thus, data were analyzed for main effects. The statistics models used were 1) $Yiik = \mu + Di + Rij + \gamma ijk$, where $Yijk$ = response variables from each individual replication or pen. μ = the overall mean; Di = the effect of diet; Rij = the inter-experimental unit (replications) error term; and γijk = the intra-experimental unit error term, and 2) $Yijk = \mu + Sj + Rij + \gamma ijk$, where $Yijk$ = response variables from each individual replication or pen, μ = the overall mean; Sj = the effect of breed; Rij = the inter-experimental unit (replications) error term; and γijk = the intra-experimental unit error term. Least significant difference comparisons were made between treatment means for main effects when there was a significant F value.

Sensory attributes that did not significantly ($P > 0.05$) discriminate between the guinea fowl samples were removed from subsequent analysis. Significant ($P < 0.05$) differences between the meats were assessed by a Tukey's honestly significant difference (**HSD**) post hoc test was then undertaken to determine which sensory attributes means significantly ($P < 0.05$) differ for the guinea fowl meat samples. After standardization (1/SD), significant ($P < 0.05$) sensory attributes were analyzed by means of principal component analysis (**PCA**) (Odero-Waitituh et al., 2021). An ANOVA was performed on the principal components to identify how each principal component discriminated between guinea fowl meat samples. Data were then averaged across replicates and a further PCA was carried out. The first 2 significant Principal Components (**PC**) were then chosen for result plotting and interpretation.

The consumer preference data were also standardized before being analyzed by means of PCA (Liu et al., 2004; Sow and Grongnet, 2010). Consumers were considered as variables and guinea fowl meat samples were considered as individuals. To segment consumers, hierarchical cluster analysis (**HCA**) with squared Euclidian distances and Ward's method were carried out on the consumer guinea fowl meat preference scores. Finally, 2 partial least squares regression models (**PLSR**) were built for studying the relationships between sensory characteristics and consumer preferences. The PLSR1 was carried out by regressing the average preference score for all consumers onto the sensory attributes for identifying the relevant guinea fowl meat sensory attributes that drive the guinea fowl preference of Ivorian consumers. The PLSR2 was undertaken by regressing the sensory characteristics onto cluster consumer preference (Byarugaba et al., 2020). The PLSR2 was also undertaken by regressing chemical composite of meat samples onto their sensorial characteristics. There is one dependent variable in PLSR1 and several dependent variables in PLSR2. The R software release 2.8.0. 3 (Copyright © 2017, The R Foundation for Statistical Computing Platform) and XLSTAT version 2014.5.03 (Copyright © 1995-2014 Addinsoft SARL, Paris, France) were used to carry out all of the basic statistical analyses and graphics.

RESULTS

Chemical Analysis

Table 3 presents the results of chemical analyses of guinea fowl thigh (Quadriceps femoris). These results show that guinea fowl fed diets C and I had statistically the same lipid levels, as did guinea fowl fed diets N and H. However, the lipid levels of guinea fowl thigh fed diets N and H were significantly higher ($P = 0.04$) than those of guinea fowl thighs fed diets C and I (respectively 3.98 and 4.15% vs. 3.56 and 3.66%). The dry matter, fat, and protein contents were statistically the same for both breeds but the ash content of Galor guinea fowl thighs was significantly higher ($P = 0.048$) than that of indigenous guinea fowl thigh.

Descriptive Sensory Analysis

Table 4 presents names, codes, and definitions of only those sensory attributes that significantly discriminated

Table 3. Chemical composition of thigh-meat (Quadriceps femoris) of 16-weeks-old guinea fowl (Galor or indigenous strains) fed different diets.

Parameter (% of FM[1])	Diet				SEM	Breed		SEM	Probability		
	I	C	N	H		Indigenous	Galor		Diet	Breed	Diet × Breed
Dry matter	26.84	26.97	26.97	27.45	0.77	26.40	27.72	0.54	0.94	0.10	0.75 (NS)
Lipids	3.66[b]	3.56[b]	3.98[a]	4.15[a]	0.30	3.77	3.90	0.21	0.04	0.66	0.68 (NS)
Proteins	22.12	22.09	21.73	22.08	0.86	21.60	22.40	0.61	0.99	0.36	0.66 (NS)
Ashes	1.06	1.32	1.26	1.22	0.18	1.02[a]	1.41[b]	0.13	0.77	$4.83e^{-2}$	0.89 (NS)

I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal.
[1]FM, fresh muscle.
[a-c]Parameter means within rows of diet or strain with no common superscript differ ($P < 0.05$).

between guinea fowl meat samples after statistical analysis was completed for the study. The mean score allocated by all assessors for each sensory attribute was calculated and an ANOVA performed to identify the sensory attributes, which discriminated between the guinea fowl meat samples (Table 5). The ANOVA results showed that three appearance attributes: (brown ($P = 0.04$), white ($P = 4.8 \times 10^{-2)}$ and yellow ($P = 2.8 \times 10^{-3}$), 3 odor attributes (oily ($P = 8.6 \times 10^{-12}$), intense ($P = 0.02$) and roasted ($P = 0.03$)), one flavor attribute (sweet ($P = 0.04$)), and 6 texture attributes (tender ($P = 0.03$), juicy $P = 0.03$, smooth ($P = 0.04$, elastic ($P = 0.01$), hard ($P = 0.01$), and fibrous ($P = 0.02$)) were significantly discriminant between the guinea fowl samples and these attributes were retained for the rest of the study. Moreover, the ANOVA results showed that the sensory panel found it easier to distinguish between guinea fowl samples using appearance and texture rather than on odor and gustatory attributes. An ANOVA also showed the lack of effect of assessors on the guinea fowl sample analysis. Thigh muscle of Galor guinea fowl was darker than indigenous guinea fowl ($P = 1.67 \times 10^{-3}$).

The significant sensory data were standardized and analyzed by means of PCA. The PCA results showed that the guinea fowl fed the different diets were well represented and were distinguishable from each other (Figure 1). The first Principal Component (PC) explained 61.5% of the sensory data variation and was mainly described by the oily appearance (r = 0.90), the juiciness (r = 0.87), the hardness (r = −0.88), the roasty odor (r = 0.987), the flavor (r = 0.92), the white color (r = −0.80), the intensity of guinea fowl odor (r = 0.89), the fibrous texture (r= −0.93) and the tenderness (r = 0.95). Figure 1 clearly shows a distinction between meat from guinea fowl fed diet I or C and meat from guinea fowl fed diet N or H. The PCA results also showed a distinction between indigenous and Galor guinea fowl. The meat of guinea fowl fed diet N or H and Galor guinea fowl meat were characterized by a strong expression of sensory attributes: oily, juicy, roasted odor, intensity of guinea fowl odor, sweet flavor, and tenderness. The second PC explained 26.7% of the sensory data variation and was mainly described by the color yellow (r = 0.93) and a smooth texture (r = −0.90). PCA results showed a distinction between guinea fowl fed diet C and guinea fowl fed diet I. It appeared that the panelists were able to differentiate the different groups of guinea fowl and particularly they made a clear distinction between indigenous guinea fowl and Galor ones.

Table 4. Sensory attributes and definitions used by the assessment panel with Statistical significance in the evaluation of guinea fowl meat samples.

Sensory characteristics	Code	Definition
Appearance		Intensity color of the surface of the cooked meat
Brown	Br	
White	Wh	
Yellow	Ye	
Odor		Overall intensity of smell
Oily	Oi	Fat odor
Intense	In	Guinea fowl odor
Roasted	Ro	Roasted meat smell
Flavor		Overall intensity of taste
Sweet	Sw	Intensity of sweetness
Texture		
Tenderness	Te	Power needed to chew
Juiciness	Ju	Amount of juice while chewing
Smoothness	Sm	Level of the softness of the guinea fowl meat between teeth
Springiness	Sp	Degree to which sample returns to its original shape after compression
Hardness	Ha	Force required to compress the sample
Fibrousness	Fb	The amount of grinding of fibers required to chew through the sample

Evaluation of Consumer Preferences

As initially indicated, consumer preferences is the overall liking of the 120 panelists. Table 6 presents the means of the 8 guinea fowl samples (2 breeds, 4 diets per breed) preference data. There was no significant preference difference between guinea fowl fed diet I and guinea fowl fed diet C. The lowest score was obtained for diet I and the highest score for diet H. Consumer preference scores were standardized and analyzed with PCA, using R 3.4.3. (Copyright © 2017, the R Foundation for Statistical Computing Platform). Figure 2 shows that the consumers had highest preference for the meat of guinea fowl fed diet H which was described as smooth (r = 0.99), juicy (r = 0.91), not hard (r = −0.85), oily odor (r = 0.95), roasted odor (r = 0.86), tender (r = 0.78). The meat of guinea fowl fed diet N showed lower preference by consumers and was also strongly characterized by the sensory attributes as roasted odor,

Table 5. Mean panel score for the descriptive sensory attributes of thigh-meat samples of 16-weeks-old guinea fowl (Galor or indigenous strains) fed different diets. The results of two-way analysis of variance (ANOVA) and Tukey's honestly significant difference (HSD).

Sensory characteristics	Diet				SEM	Breed		SEM	Probability		
	I	C	N	H		Indigenous	Galor		Diet	Breed	Diet × Breed
Appearance											
Brown	3.19^{a}	3.07^{b}	3.08^{b}	3.25^{a}	0.11	2.98^{b}	3.32^{a}	0.08	0.04	1.6^{e-3}	0.65
White	1.88^{a}	1.83^{a}	1.70^{b}	1.75^{b}	0.09	1.81	1.78	0.06	0.48	0.71	0.34
Yellow	1.83^{b}	2.34^{a}	2.22^{a}	2.25^{a}	0.11	2.26^{a}	2.06^{b}	0.07	2.8^{e-3}	0.03	0.46
Odor											
Oily	2.43^{ab}	2.04^{b}	2.57^{a}	3.17^{c}	0.11	2.40^{b}	2.70^{a}	0.08	8.6^{e-12}	4^{e-3}	0.91
Intense	2.53^{b}	2.51^{b}	2.59^{ab}	2.73^{a}	0.10	2.49	2.69	0.07	0.02	0.06	0.61
Roasted	2.70^{b}	2.74^{ab}	2.81^{ab}	2.95^{a}	0.10	2.76	2.84	0.07	0.03	0.41	0.34
Flavor											
Sweet	3.19^{b}	3.23^{b}	3.28^{a}	3.33^{a}	0.09	3.25	3.26	0.07	0.04	0.96	0.33
Texture											
Tender	2.67^{b}	2.82^{ab}	2.92^{ab}	3.07^{a}	0.10	2.84	2.90	0.07	0.03	0.54	0.12
Juicy	2.39^{ab}	2.25^{b}	2.56^{a}	2.61^{a}	0.10	2.35^{b}	2.55^{a}	0.07	0.03	0.03	0.40
Smooth	2.80^{a}	2.53^{b}	2.62^{ab}	2.70^{ab}	0.10	2.65	2.67	0.07	0.04	0.87	0.14
Springy	1.86^{b}	2.06^{a}	2.08^{a}	2.14^{a}	0.10	2.10	1.97	0.07	0.01	0.16	0.73
Hard	2.21^{a}	2.21^{a}	2.14^{ab}	1.76^{b}	0.11	2.08	2.08	0.08	0.01	0.94	0.14
Fibrous	2.30^{b}	2.24^{b}	2.53^{a}	2.41^{ab}	0.11	2.44	2.30	0.08	0.02	0.22	0.80

I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal.

[a-c]Parameter means within rows of diet or strain with no common superscript differ ($P < 0.05$).

tenderness, elasticity, and yellow color. The meats of guinea fowl fed diet C or I were preferred least by consumers who strongly characterized the sensory attributes as white, hard, and fibrous meat. Average values are useful to determine general tendencies but do not inform about groups of people that can prefer some products to others and vice versa. To identify these groups, different techniques of consumers' segmentation have been applied such as the Hierarchical Cluster Analysis (HCA).

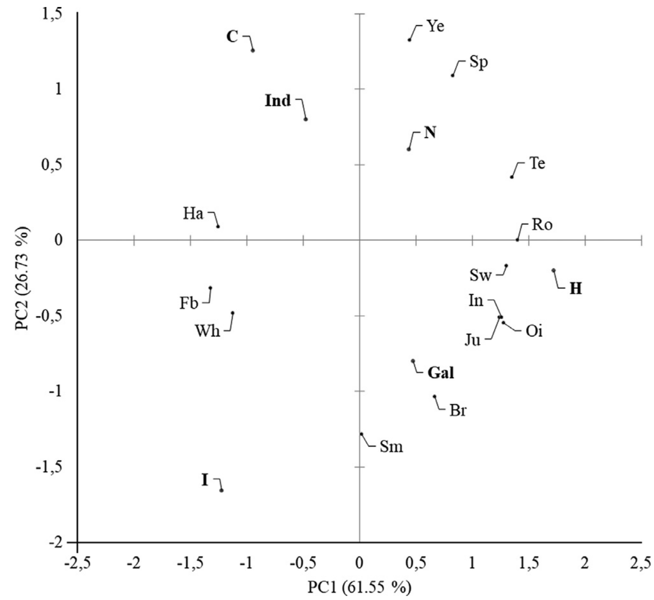

Figure 1. Principal component analysis results showing the description of the four guinea fowl samples by the 13 sensory attributes: I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal. Ind = indigenous guinea fowl; Gal = Galor guinea fowl. Br = the intensity of the brown color of the meat; Wh = the intensity of the white color of the meat; Ye = the intensity of the yellow color of the meat; Oi = the extent of the fat odor of the meat; In = the extent of the guinea fowl odor; Ro = the extent of the smell of the roast; Sw = intensity of sweetness taste on the tongue; Te = the intensity of the tenderness of the guinea fowl meat; Ju = the ability of guinea fowl meat to produce juice in the mouth; Sm = the level of the softness of the guinea fowl meat between teeth; Sp = the degree of elasticity of the guinea fowl meat; Ha = the extent to which the guinea fowl meat requires efforts when chewing; Fb = the fibrous nature of the guinea fowl meat found when masticating; PC1 = principal component 1; PC2 = principal component 2.

HCA of the Consumer Preference Data

HCA is a statistical method to find homogenous clusters of consumers based on their preferences. This method has led to the identification of 3 groups of consumers with a homogenous preference for guinea fowl meat (Table 6). The meat the most appreciated by consumers was the meat from guinea fowl fed diet H and the least appreciated came from guinea fowl fed commercial diet I ($P = 1.83 \times 10^{-2}$). However, Figure 3 shows that the analysis of the preference scores within each of the three groups (clusters) showed some preference differences between all the guinea fowl samples. The group 2 is the biggest cluster of consumers and the group 3 is the smallest one (respectively 41.7 and 28.3% of the consumers) and both groups exhibited the highest preference scores for meat from guinea fowl fed diet H (respectively $P = 1.8 \times 10^{-2}$ and 10^{-4}). Groups 2 and 3 did not appreciate (lowest preference scores) the meat from guinea fowl fed diet N or I. Among consumers of these 2 groups, the majority (86.7%) were under 25 yr old and represented 75% of the female panelists (30 out of a total of 40). More than half of the consumers of both groups 2 and 3 (62.4%) originated from the South or the West of Côte d'Ivoire. The other consumers (37.6%) originated from the Center or East of the country. Group 1 (30% of consumers) highly appreciated the meat from guinea fowl fed the diet N and disliked the meat from guinea fowl fed diet I, C or H. Among consumers of this group 1, 96.2% were under 25 yr of age

Table 6. Results of the hierarchical cluster analysis of the consumer preference data, for thigh-meat samples of 16-wk-old guinea fowl (Galor or indigenous strains) fed different diets, showing homogenous consumer clusters, 2-way ANOVA, and Tukey least significant difference (LSD) test results.

Cluster	Cluster size	Diet				SEM	Breed		SEM	Probability		
		I	C	N	H		Indigenous	Galor		Diet	Breed	Diet × Breed
1	36	$3.17^{B,b}$	$3.17^{B,b}$	$4.44^{A,c}$	$3.17^{B,b}$	0.639	3.47	3.50	0.020	1^{e-4}	0.855	1^{e-4}
2	50	$3.44^{C,a}$	$3.56^{B,a}$	$3.32^{C,a}$	$3.76^{A,c}$	0.188	3.50	3.54	0.028	1.8^{e-2}	0.785	1^{e-4}
3	34	$3.24^{B,b}$	$3.53^{D,a}$	$3.06^{C,b}$	$4.26^{A,a}$	0.532	3.50	3.54	0.031	1^{e-4}	0.757	1^{e-4}
SEM	0.550	0.142	0.142	0.219	0.736	0.016	0.024	-	-	-	-	
P-value	2^{e-4}	$3^{\ e-4}$	$3^{\ e-4}$	$4^{\ e-4}$	1^{e-4}	0.98	0.97	-	-	-	-	
All	120	3.30^{C}	3.43^{C}	3.58^{B}	3.73^{A}	0.184	3.49	3.53	0.027	1.83^{e-2}	0.71	6^{e-4}

I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal.

[a-c]Means within a column with the same superscript are not significantly different according to Tukey LSD test results.

[A-D]Means within a row of diet or strain with the same superscript are not significantly different according to Tukey LSD test results.

and this group represented 25% of the female panelists (10 out of a total of 40). Most of the consumers of group 1 (76.3%) originated from the Center or East of Côte d'Ivoire

Relationship Between Sensorial Attributes and Chemical Characteristics of Meat Samples

A PLSR2 (multiple responses) model was used to study relationships between meat sample sensorial

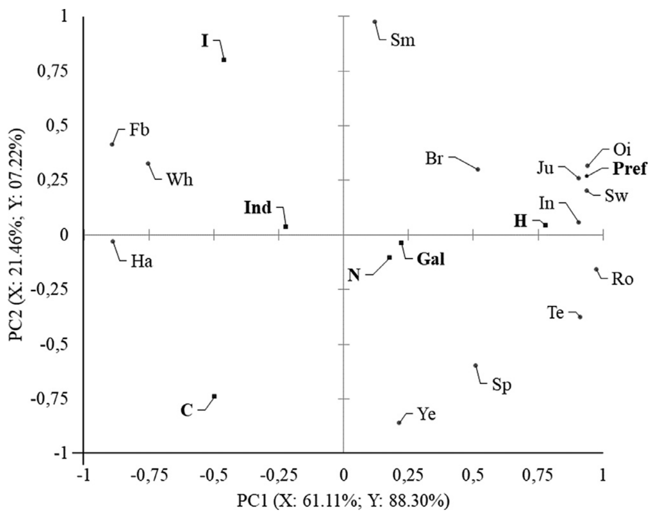

Figure 2. Partial least squares regression model 1 results showing the relationship between guinea fowl sensory attributes and consumer's overall guinea fowl sample preference (Pref) score: I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal.Ind = indigenous guinea fowl; Gal = Galor guinea fowl. Br = the intensity of the brown color of the meat; Wh = the intensity of the white color of the meat; Ye = the intensity of the yellow color of the meat; Oi = the extent of the fat odor of the meat; In = the extent of the guinea fowl odor; Ro = the extent of the smell of the roast; Sw = intensity of sweetness taste on the tongue; Te = the intensity of the tenderness of the guinea fowl meat; Ju = the ability of guinea fowl meat to produce juice in the mouth; Sm = the level of the softness of the guinea fowl meat between teeth; Sp = the degree of elasticity of the guinea fowl meat; Ha = the extent to which the guinea fowl meat requires efforts when chewing; Fb = the fibrous nature of the guinea fowl meat found when masticating; PC1 = principal component 1; PC2 = principal component 2.

attributes and their chemical characteristics. In this section, we used the PLSR2 model to describe the sensory attributes of the guinea fowl meat. In this model, we considered sensory attributes as predictors and chemical characteristics as explanatory variables. The results obtained from PLSR were a mapping of sensory attributes showing graphic visualization of meat guinea fowl samples and their chemical characteristics. Figure 4 presents the results of the model and shows that 91% of the chemical data for the first 2 Principal Components Analyses explain 68% of the guinea fowl sensory attributes. The tenderness, characteristic of the guinea fowl fed diet H, was positively correlated with lipids (r = 0.86). In addition, the lipid content of the meat was positively correlated with the juiciness of the meat (r = 0.94). The mild flavor, oily and roasted odor that characterize the guinea fowl fed diet H are positively correlated with meat lipids (respectively, r = 0.98, r = 0.93 and r = 0, 91). Moreover, the characteristic brown coloring of meat of guinea fowl is positively related to its dry matter content (r = 0.90), in particular to its protein content (r = 0.87).

DISCUSSION

Guinea fowl production is increasing in developing countries, like the Côte d'Ivoire, where there is an increasing demand for their meat (Kouassi et al., 2019). Information about the quality of guinea fowl meat and consumer acceptance is therefore important and no study on these aspects has ever been undertaken to our knowledge. In their review on poultry meat quality, Sokołowicz et al. (2016) reminded that the 2 most important quality attributes were appearance and texture. Texture is probably the most important quality factor associated with consumer satisfaction in the eating quality of poultry. Our results accord with these results and also with results on Guinean chickens (Sow and Grongnet, 2010).

In our study, the consumers attributed high 'liking' scores for the meat of guinea fowl fed diet H whatever the breed. They also could distinguish between meat from Galor guinea fowl and from indigenous breed of guinea fowl. Food choice motives and the related

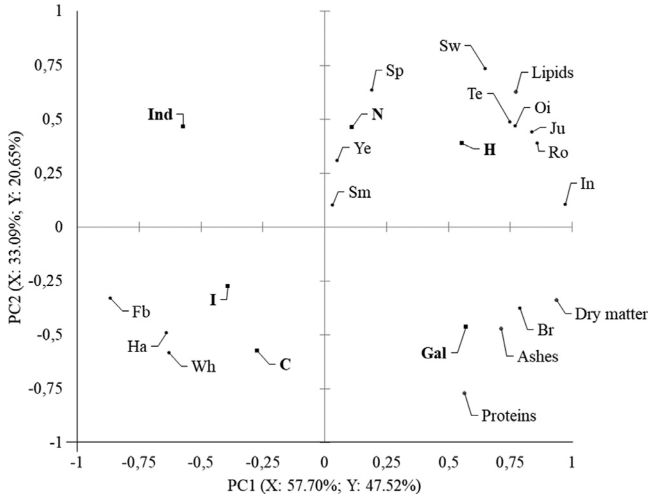

Figure 3. Partial least squares regression model two results showing the relationship between guinea fowl meat samples, their sensory attributes and their chemical characteristics: I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal. Ind = indigenous guinea fowl; Gal = Galor guinea fowl. Br = the intensity of the brown color of the meat; Wh = the intensity of the white color of the meat; Ye = the intensity of the yellow color of the meat; Oi = the extent of the fat odor of the meat; In = the extent of the guinea fowl odor; Ro = the extent of the smell of the roast; Sw = intensity of sweetness taste on the tongue; Te = the intensity of the tenderness of the guinea fowl meat; Ju = the ability of guinea fowl meat to produce juice in the mouth; Sm = the level of the softness of the guinea fowl meat between teeth; Sp = the degree of elasticity of the guinea fowl meat; Ha = the extent to which the guinea fowl meat requires efforts when chewing; Fb = the fibrous nature of the guinea fowl meat found when masticating; PC1 = principal component 1; PC2 = principal component 2.

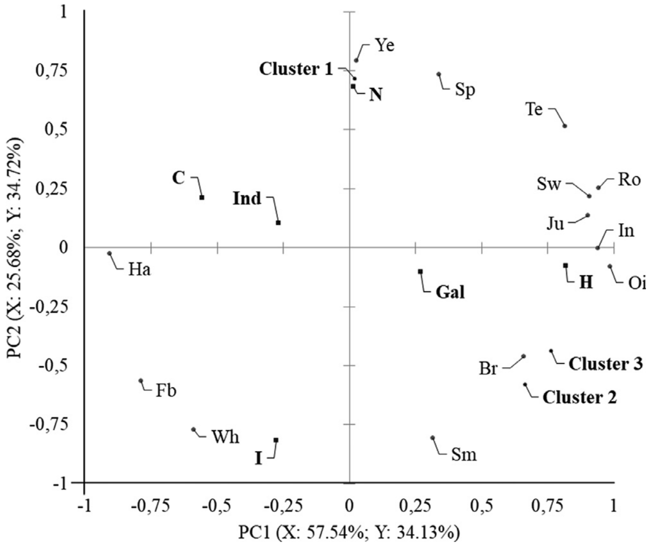

Figure 4. Partial least squares regression model 2 results showing the external preference mapping of the chicken samples, their sensory attributes, and consumer clusters: I = grower commercial diet (Ivograin); C = control grower meal diet; N = grower meal diet C supplemented with 15% cashew nut *Anacardium occidentale*) meal; H = grower meal diet C supplemented with 15% detoxified hevea seed (*Hevea brasiliensis*) meal. Ind = indigenous guinea fowl; Gal = Galor guinea fowl. Br = the intensity of the brown color of the meat; Wh = the intensity of the white color of the meat; Ye = the intensity of the yellow color of the meat; Oi = the extent of the fat odor of the meat; In = the extent of the guinea fowl odor; Ro = the extent of the smell of the roast; Sw = intensity of sweetness taste on the tongue; Te = the intensity of the tenderness of the guinea fowl meat; Ju = the ability of guinea fowl meat to produce juice in the mouth; Sm = the level of the softness of the guinea fowl meat between teeth; Sp = the degree of elasticity of the guinea fowl meat; Ha = the extent to which the guinea fowl meat requires efforts when chewing; Fb = the fibrous nature of the guinea fowl meat found when masticating; PC1 = principal component 1; PC2 = principal component 2.

importance of consumers for product attributes are valuable segmentation bases (Verain et al., 2016), as they determine largely what food choices consumers make. The importance of food attributes indicates people's underlying motives for their food choices (Carbonel et al., 2008). Average values are useful to determine general tendencies but do not inform about groups of people who have different preferences.

To identify these groups, different techniques of consumers' segmentation were applied such as the Hierarchical Cluster Analysis (HCA). The distribution of consumer preferences was very heterogeneous and this result is in accordance with (Byarugaba et al., 2020) who studied consumer preference for cooked chicken breasts from organic, free-range, and conventional systems. Sow and Grongnet in 2010 evaluated Guinean preference for live village chickens, live broilers and live spent laying hens and found the same heterogeneity among consumer preferences (Sow and Grongnet, 2010). The inclusion of women in the study panel is very important. They play a crucial role in food supply for their family and poverty reduction in developing countries (Aromolaran, 2004). Indeed, when women control production or purchases of animal and plant products, the nutritional and health status of the family are highly improved.

Common statistical package clustering (**SPC**) methods may identify consumer segments that are heterogeneous in product acceptance. Creating new products based on attributes selected from preference maps that use those clusters may result in product failure because the products are developed for consumers with some dissimilar preferences. A PLSR2 (multiple responses) model was used to study relationships between sensorial attributes and chemical characteristics of meat samples; this method was used by Chumngoen and Tan (2015) who worked on broiler and Taiwan native chicken breast meat, and Amorim et al. (2016) who compared physicochemical and sensory characteristics of capons and roasters. They found that the fat content of the meat determined its intensity of flavor, juiciness, and tenderness, as observed in guinea fowl in our study. This was also observed in beef (May et al., 1992; Mottram, 1998; Jeremiah et al., 2003; Muchenje et al., 2010).

It has been identified that natural components have little aroma in meat until cooked (Parker et al., 2006). Complex processes such as lipid oxidation, thermal degradation of thiamine, and Maillard reactions combine to improve the taste of poultry (Aliani and Farmer 2005; Dyubele et al., 2010). It is well known that the flavor and aroma come from the fats that become volatile when heated. In addition, in poultry meat, 450 compounds produce flavor (Parker et al., 2006). The composition and amount of fat also determines the intensity of the flavor in the meat (Muchenje et al., 2010). Thus, the positive link between intramuscular lipids and juiciness (Jeremiah et al., 2003), flavor (Mottram, 1998), and tenderness of meat (May et al., 1992) was confirmed.

The study shows that Galor guinea fowl thigh muscle is darker than that of indigenous guinea fowl. This is in accordance with Chumngoen and Tan (2015), who found broiler meat darker than meat from local breed. However, this result contrasts to the findings of Cassandro et al. (2015) who showed that breast muscles of indigenous Padovana chickens were darker than commercial broiler meat. However, the breast muscle color of guinea fowl tends to be darker than that of chickens showing species difference (Laudadio et al., 2012). Redness of guinea fowl breast muscles was observed to decrease with age, as it is also the case for chickens (Kokoszynski et al., 2011; Wideman et al., 2016).

In conclusion, this study has identified sensory attributes and consumer preference for guinea fowl meat in Côte d'Ivoire. Our findings showed that the meat from guinea fowl fed a diet supplemented with *Hevea brasiliensis* seeds was highly appreciated and preferred. This confirms that a place exists for the use of hevea seed meal in guinea fowl diet in Côte d'Ivoire. Therefore, supplementation of diets with *Hevea brasiliensis* to, at least partly, replace soybean meal at a lower cost can be developed in Cote d'Ivoire, thereby reducing feed costs and consequently also reducing guinea fowl production costs.

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DISCLOSURES

The authors declare that they have no conflict of interest to this work.

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