INTRODUCTION

The groundnut (*Arachis hypogaea* L.) is a self-pollinated, tropical annual legume that belongs to the family of *Papilionaceae*. The groundnut is native to South America and is one of the most cultivated oilseeds in Western Africa and even in the world for its seeds with high oil content[1,2]. Over 100 countries worldwide grow groundnut. The production of groundnut is concentrated in Asia and Africa (56% and 40% of the global area and 68 and 25% of the global production, respectively). Most of the commercially cultivated varieties belong to the *hypogaea* (common name/market type: Virginia or runner), *fastigiata* (valencia), and *vulgaris* (Spanish) botanical variety groups. After the pods containing the seeds have been harvested, the groundnut produces a residue, which constitutes agricultural residues used in animal feed[3]. The hay is the part of the plant that remains in the field after harvesting ripe pods on an annual plant such as groundnut, soybeans and beans[4].

In West Africa, groundnut hay is used mainly for animal feed. It is little used since this crop is harvested before the end of the rains. Consequently, most of the hay samples rot in the field. In rural areas, the groundnut hay is intended for privileged animals such as horses, dairy cows, weaned youngsters and traction cattle. In urban areas, it is intended for house sheep and horses. When the hay is harvested, the average of its nutritional value is 0.83 Fodder Unit per kg of dry matter[5]. Indeed, the fodder unit (UF) is the unit used to determine the energizing value of a fodder. This unit refers to the energizing value of 1 kg of barley harvested to the stage mature grain that corresponds in 1 UF.

Groundnut hay is an important source of protein and an alternative source of raw material to lower the cost of producing animal foods. For example, in the poultry industry, the groundnut hays is attractive as substituting 6% of concentrate mixture with groundnut hays resulted in a 15% increase in the live body weight of broilers compared to the controls[6]. The substantial increase observed was attributed to high nutrient availability in groundnut hays[6]. Indeed Crude protein concentration of haulms of many groundnut cultivars ranges from 8 to 15%[7,8]. Digestibility of groundnut hays ranges from 74 to 88% in ruminants and support animals' growth performance[7,9,10]. It is to address this issue that this study is initiated to generate data essential to the valorization of the groundnut hays in Côte d'Ivoire. The general objective of this study was to promote groundnut hay in animal feed that would allow farmers to make a profit from their activity reducing the cost of industrial animal foods. Specifically, the study aims to determine the yield and nutritional characteristics of the hay from five groundnut cultivars collected in the Korhogo department.

MATERIALS AND METHODS

Study area: The study was carried out in the department of Korhogo where groundnut seeds were collected in two localities that are Torgokaha and Zanapkokaha (Fig. 1) from January to March 2017. Then the yields of hay were assessed after seed sowing in Fisher Block design from September to November 2017 at the University of Peleforo Gon Coulibaly (UPGC) (Fig. 1). The climate in the department of Korhogo is characterized by an alternation of two seasons: dry season very marked by the harmattan between December and January with high values of heat in March and April. The rainy season extends from May to October with maximum rainfall in July and August. The Sudano-Guinean savannah at the study site is a transition zone between the forest and savannah zone of Northern Côte d'Ivoire, where annual precipitations vary between 1,200 and 1,500 mm. Laboratory analyses took place at Abidjan Southern Côte d'Ivoire from January to February 2018.

Plant material: The plant material involved five groundnut cultivars collected as seeds, introduced into the collection of the University of Peleforo Gon Coulibaly under code numbers PA11, PA12, PA13, PA14 and PA15.

Evaluation of the hay yields: To assess the hay yields for five groundnut cultivars, the seeds were sown in a Fisher block design with three replicates at UPGC. The seeding density was 150 943 plants per hectare. At the end of the pod production cycle 90 days for the cultivar PA13 and 120 days for the cultivars PA15, PA14, PA12 and PA11, the yields per hectare of hay (R1) were estimated. For one cultivar, 10 groundnut plants without pods were weighed and the average was multiplied by 150 943 (number of groundnut plants per hectare). For each cultivar the hay yield was compared to the estimated pod yield (R1) and seed yield (R2) ratio according to the following mathematical expressions:

$$R2\left(kg\,ha^{-1}\right)=\frac{\text{Hay yield}}{\text{Pod yield}}$$

$$R3\left(kg\,ha^{-1}\right)=\frac{\text{Hay yield}}{\text{Seed yield}}$$

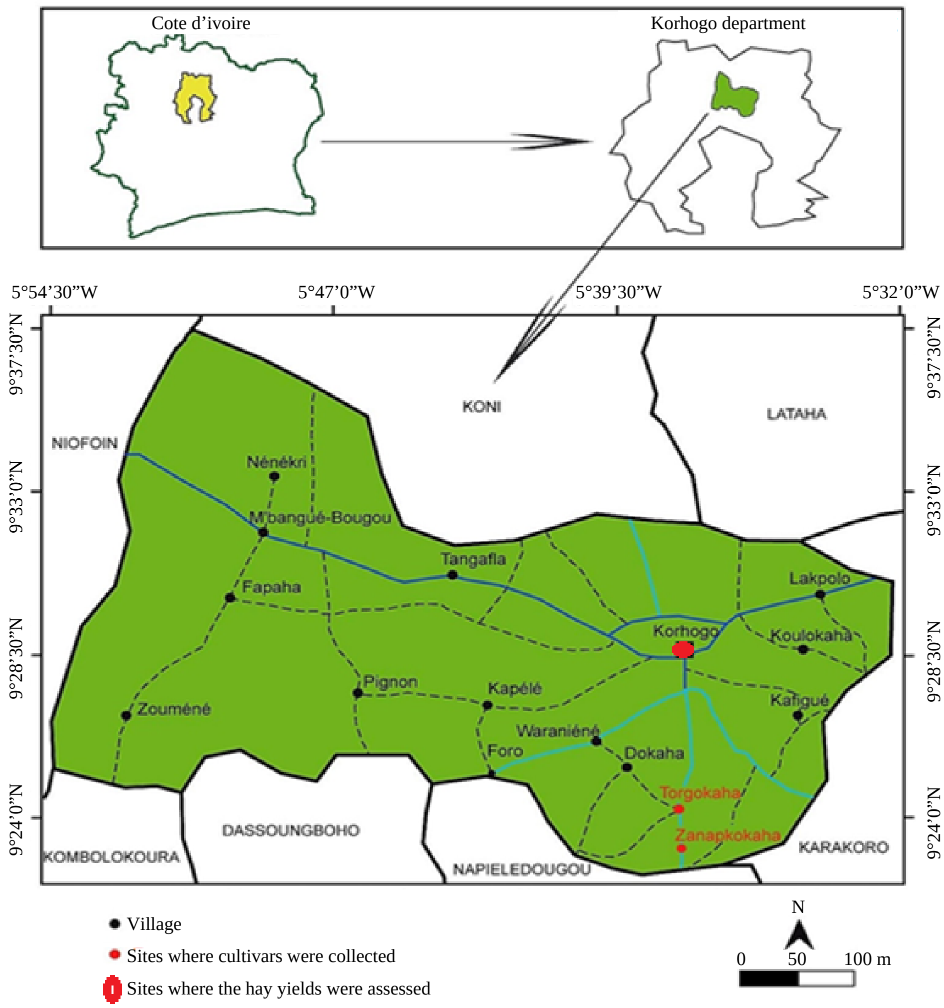

Fig. 1: The geographic map showing the sites where groundnut cultivars were collected and the yields of hay were assessed (Source: Groundnut program of University of Peleforo Gon Coulibaly, Côte d'Ivoire, January 2020)

Assessment of the hay nutrient contents of the groundnut cultivars: Five plants were selected per block to constitute three hay samples for each groundnut cultivar. Laboratory analyses were performed on dried samples of groundnut hay. Ten nutrient compounds were determined at the laboratory on 15 dried hay samples (three samples per groundnut cultivar). Dry matter contents were determined from 5 g of hay flours after drying 105°C until a constant weight following the protocol described in detail by Bomisso *et al.*[11]. The ash content of the hay was quantified according to Aboagarib *et al.*[12]. Total sugars contents were determined according to the protocol of Dubois *et al.*[13] and reducing sugars contents according to Bernfeld[14]. The determination of hay proteins was carried out by the Kjeldahl method after the determination of total nitrogen content. The crude protein content of the hay was deduced from the nitrogen level using 6.25 as conversion coefficient[15]. The lipid content of the hay flour was determined by the classical Soxhlet method[12] with n-hexane as solvent. Lipids were quantified from 10 g of hay flour sample by solvent extraction using 300 mL of n-hexane reagent for 7 h. The difference between the sample weight before and after the experiment allowed the estimation of the lipid contents. The total carbohydrate content and energy value (E) were calculated following mathematical expressions[12]:

$$\text{Total carbohydrates (\%)} = 100 - (\text{Ash (\%)} + \text{Moisture (\%)} + \text{Protein (\%)} + \text{Lipids (\%)})$$

$$E\ (\text{KCl/100 g}) = (4\times\text{Protein}) + (9\times\text{Lipid}) + (4\times\text{Total carbohydrates})$$

The oxalate contents were assessed[12]. A quantity of 2 g of hay flour sample was homogenized into 200 mL of distilled water and added with 20 mL of 6N hydrochloric acid (HCl). The mixture was heated in a boiling water bath for 1 h, cooled, and filtered. Fifty milliliters of the filtrate were then homogenized into 20 mL of 6 N HCl and filtered again. The second filtrate was treated with methyl red (0.1%, w/v), concentrated ammonia, heated, and filtered. The third filtrate was boiled, treated with calcium chloride (5%, w/v) for the formation of calcium oxalate crystals, and then filtered once more. The residues deriving from the filtration steps were successively washed with distilled boiling water, dried into an oven; dissolved into 10 mL of diluted sulfuric acid, and titrated with 0.05N potassium permanganate solution. The phytate content was quantified according to the method of Mohammed *et al.*[16]. A quantity of 0.5 g of hay sample was treated with 25 mL of TCA solution at 3% (w/v) and centrifuged at 3,500 rpm for 15 min. Five milliliters of the supernatant was removed, treated with 3 mL of ferric chloride 1% (w/v) reagent, heated in a boiling water bath, cooled and also centrifuged at 3,500 rpm for 10 min. The second supernatant was treated with 5 mL of 0.5N hydrochloric acid, 5 mL of 1.5 N sodium hydroxide, heated in a boiling water bath and centrifuged once more at 3500 rpm for 10 min. Thus, 1 mL of the final supernatant was added with 4.5 mL of distilled water and 4.5 mL of ortho-phenanthroline reagent and then measured for the absorbance at 470 nm with a spectrophotometer against standard Mohr salt solution treated likewise and taken as phytates ferric control.

Data analysis: The data collected was digitized under Excel office 2010 software to produce the graphics. Statistica version 7.1 (StatSoft Inc., France) software was used to determine descriptive statistic parameters such as the means and the standard deviations. Also, an analysis of variance (ANOVA) was performed to differentiate the groundnut cultivars from yields and nutritional profile of hay at a probability threshold of 0.05.

RESULTS

Hay yields of groundnut cultivars: Significant differences ($p<0.05$) between mean values of hay yields were recorded for PA11, PA12, PA13, PA14 and PA15 groundnut cultivars (Fig. 2). PA14 cultivar was recorded a higher mean value of hay yield (90.64 kg ha^{-1}) than that of the other cultivars. This cultivar with high hay output is followed from the cultivar PA13 that produced an average hay yield of 79.19 kg ha^{-1}. PA15 and PA11 groundnut cultivars were produced the lowest hay yields with 68.38 and 69.54 kg ha^{-1} mean values respectively. During the harvest, 100 kg of harvested pods corresponds to 11 to 19 kg of harvested hay. Similarly, 100 kg of seeds harvested corresponds to 21 to 39 kg of harvested groundnut hays (Table 1).

Dry matter and ash contents of hay: The dry matter content ranged from 94.67% to 96.29% in the groundnut hay cultivars studied. The differences observed between the dry matter contents in the cultivar hays were significant at the 5% probability level. The dry matter content was higher in PA12 (96.29%) and lower in PA15 (94.67%).

Hay ash contents from groundnut cultivars varied from 2.11 g/100 g to 2.74 g/100 g of Dry Matter (DM). Hay ash content was high in PA15 cultivar (2.74 g/100 g of DM) and lower in PA14 cultivar (2.11 g/100 g of DM) (Table 2).

Table 1: The output of hay (R1) in relation to the outputs of pods (R2 ratio) and seeds (R3 ratio) from five groundnut cultivars collected in Korhogo department

	PA11	PA12	PA13	PA14	PA15
Pod yield (kg ha^{-1})	573.00	671.00	381.67	724.00	357.00
Seed yield (kg ha^{-1})	334.33	339.00	228.33	316.67	180.67
R1 or Hay yield (kg ha^{-1})	69.54	72.76	79.19	90.64	68.38
R2 ratio or Hay yield/Pod yield	0.12	0.11	0.19	0.13	0.19
R3 ratio or Hay yield/Seed yield	0.21	0.21	0.35	0.29	0.39

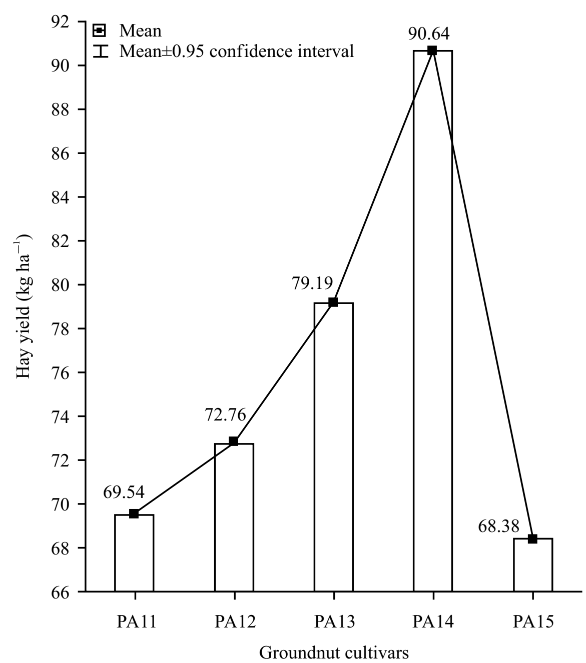

Fig. 2: Means of hay yields of five groundnut cultivars from Korhogo department

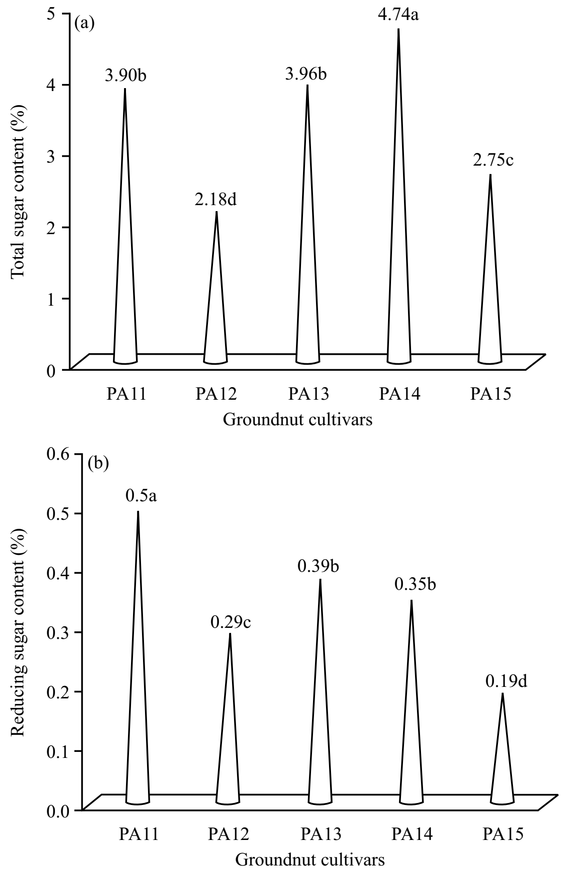

Fig. 3: Contents of (a) Hay total sugar content and (b) Hay reducing sugar content of five groundnut cultivars from Korhogo department. Mean values followed by different scripts are statistically different at 5% significance

Sugar, lipid, protein and total carbohydrate contents of groundnut hay: The total F = 1627.58, p<0.001) and reducing (F = 251,61, p<0.001) sugar contents of the hays significantly differentiated the groundnut cultivars (Fig. 3a-b). In groundnut hays, the total sugar content ranged from 2.18 % to 4.74%. Reducing sugar content ranged from 0.19 % to 0.50%. The cultivars PA11, PA13 and P14 provided the highest values of total sugars (3.90-4.74%) and non-reducing sugars (0.35-0.50%) (Fig. 3). The total carbohydrate (F = 55.69, p<0.001), protein (F = 74497.58, p<0.001) and lipid (F = 7.36, p<0.,001) contents varied significantly from one groundnut cultivar to another (Fi. 4a-c). The hays of PA12 and PA15 groundnut cultivars recorded respectively higher (76.42%) and weak (73.21%) mean values of carbohydrate contents. The hay protein content varying from 13.93-16.8% was higher in PA14 (16.23%) and PA15 (16.28%). For all the studied hays, the lipid content ranging from 1.82 % to 3.42% was higher in PA11 (3.42%) (Fig. 4). In groundnut hays, the proportion of carbohydrates (73.21-76.42%) was higher than the protein (13.43-16.80%) and fat (1.82-3.42%) contents.

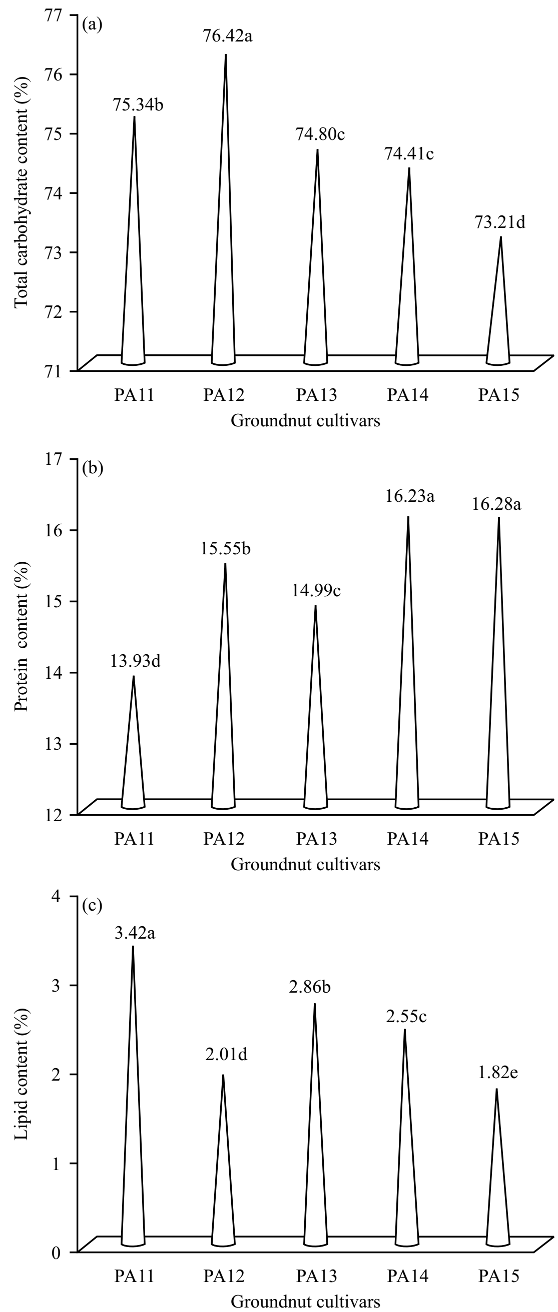

Fig. 4: Content of (a) Hay carbohydrate, (b) Hay protein and (c) Hay lipid of five groundnut cultivars from Korhogo department. Mean values followed by different scripts are statistically different at 5% significance

Energy values and anti-nutritional components of groundnut hay: The hay energy values discriminated significantly the groundnut cultivars (F = 5.51, p<0.001). The

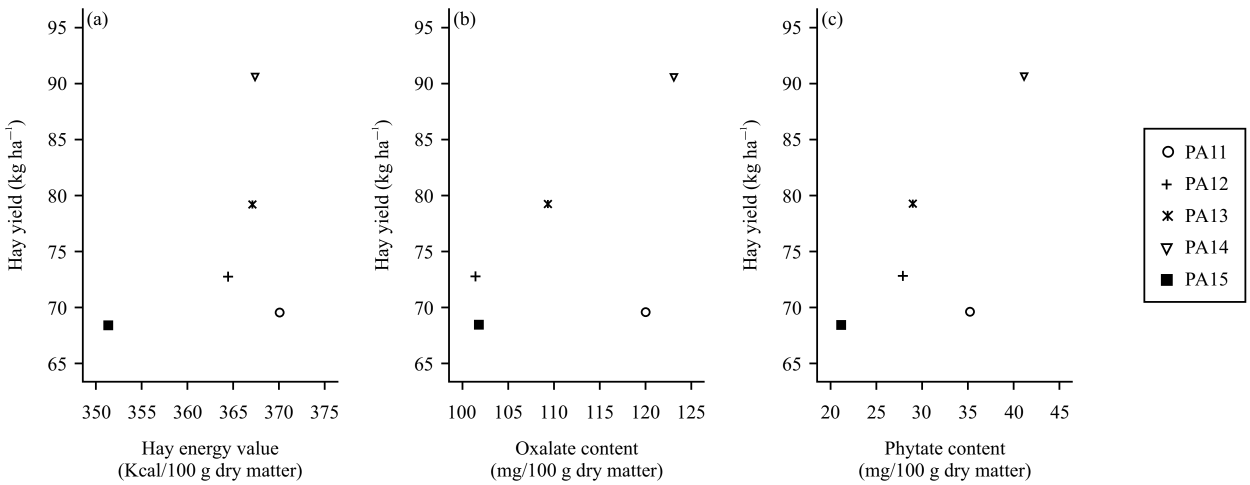

Fig. 5: Simple scatter plots showing groundnut cultivar clusters in plans formed from (a) hay yields and hay energy values, (b) hay yields and oxalate contents and (c) hay yields and phytate contents

Table 2: Dry matter and ash contents of harvested hay from five groundnut cultivars collected in Korhogo department

Biochemical characteristics	PA11	PA12	PA13	PA14	PA15	F	p
Dry matter or DM (%)	95.02 ± 0.02^{c}	96.29 ± 0.02^{a}	94.90 ± 0.02^{d}	95.27 ± 0.02^{b}	94.67 ± 0.02^{e}	4493.94	<0.001
Ash (g/100g of DM)	2.33 ± 0.19^{ab}	2.34 ± 0.24^{ab}	2.26 ± 0.04^{ab}	2.11 ± 0.14^{b}	2.74 ± 0.33^{a}	3.65	0.044

Per raw, values followed by different scripts are statistically different at 5% significance , F: Statistic value of ANOVA test, p: p-value associated to ANOVA test

Table 3: Anti-nutritional substance contents of harvested hay from five groundnut cultivars collected in Korhogo department

Anti-nutritional components	PA11	PA12	PA13	PA14	PA15	F	p
Oxalate (mg/100 g DM)	119.94 ± 0.97^{a}	101.45 ± 2.01^{c}	109.33 ± 1.44^{b}	$123.01\pm3{,}08^{a}$	101.82 ± 2.55^{c}	150.18	<0.001
Phytate (mg/100 g DM)	35.20 ± 0.94^{b}	27.86 ± 1.48^{c}	28.96 ± 0.85^{c}	41.09 ± 1.17^{a}	21.14 ± 0.76^{d}	65.37	<0.001

Per raw, values followed by different scripts are statistically different at 5% significance, F: Statistic value of ANOVA test, p: p-value associated to ANOVA test, DM: Dry matter

cultivars PA11 (370.07 kcal/100 g), PA13 (367.07 kcal/100 g) and PA14 (367.39 kcal/100 g) recorded higher energy values of the groundnut hay. The PA15 (351.34 kcal/100 g) cultivar presented the lowest energy value of all studied cultivars. The PA14 cultivar was given at the same time high yield of hay with high energy value (Fig. 5a).

The oxalate and phytate contents of the hays significantly differentiated the groundnut cultivars (Table 3). The oxalate contents varied from 101.45 mg/100 g dry matter (DM) to 123.01 mg/100 g DM. It was higher in PA14 (123.01 mg/100 g DM) and lower in PA12 (101.45 mg/100 g of DM). The phytate contents varied from 21.14±0.76 mg/100 g to 41.09±1.17 mg/100 g. It had the highest value in PA14 (41.09±1.17 mg/100 g) and lowest in PA15 (21.14±0.76 mg/100 g) (Table 3). The PA14 cultivar was given at the same time high yield of hay with high oxalate and phytate contents (Fig. 5b,c).

DISCUSSION

The results showed that P14 cultivar products high hay output. These results showed that for hay valorization in livestock nutrition, the cultivation of the PA14 cultivar would be more profitable for the farmer with regard to its high hay yield.

The hays of groundnut cultivar recorded high values of dry matter content varying from 96.29 to 94.67%. The dry matter content of food determines the fraction of nutritive elements effectively ingested that influences the growth and the harmonious development of the animal. Indeed the food rich in dry matter is beneficial for lactation and the need energizing. Therefore, it is current to value food for animals and to balance the rations while being based on dry matter. In the present study, the dry matter rates in groundnut cultivar hays were very high (all mean values were more than 90%). Dry matter contents from hay samples in groundnut cultivars collected at the Korhogo department were more than the ones from fodder trees *Pterocarpus lucens* (41.76%), *Pterocarpus erinaceus* (34.82%) and *Ficus gnaphalocarpa* (29.58%) collected at Mali as reported by Nantoumé *et al.*[17]. This result is consistent with that revealed in previous studies on groundnut hay that the dry matter contents are 93.42%, 92.4% and 92.5%[17,18,19]. Based on the dry matter rate, the groundnut hays seem to be beneficial for livestock nutrition. In the present study, the hay ash content varied from 2.74 g/100 g of DM (Dry matter) to 2.11 g/100 g of DM. The rate of ash in a food informs its composition in minerals. The deficit in minerals dragged of the disruptions to the level of growth and the fertility of the livestock. The mean values of hay ash contents found in the present survey are weak to those previously reported in groundnut hay sampled in Mali (hay ash content = 7.92% of DM)[17]. The weak values of ash contents of the groundnut cultivars would be caused by poverty in mineral contents of the soils where groundnut cultivars were cultivated especially as the experiment has been realized without organic or mineral manure supply.

There is a variability of nutrients in groundnut hay such as sugars, carbohydrates, proteins and lipids. They are very important in animal feed and even in animal production. Indeed, the provision of a ration concentrated in nutritive elements is necessary so that the livestock cannot be in a state of deficiency and also externalize their production potential. So, the variability of hay nutritive characteristics could lead to a varietal improvement to obtain animal foods. It was reported that groundnut hays consumption by broiler increases their live body weight. This was attributed to high nutrient availability in groundnut hays[6]. The mean values of protein and lipid contents found in the present survey are similar to those previously reported in groundnut hay sampled in Mali (hay protein content = 17.09%; hay lipid content = 2.18%)[17]. These high levels of nutrients show the good quality of the groundnut hay. According to Ntare *et al.*[20], the nutritional value of the hay increases if a few more or less aborted pods still adhere to the root, which was the case in the field.

The PA14 cultivar was given at the same time a high yield of hay with high energy value. This result showed that for the promotion of groundnut hay from PA14 cultivar would be more profitable for livestock nutrition. The present study focused on the valorization of groundnut hays in livestock nutrition. It appears that in the five groundnut cultivars, there are nutrients in the hays such as minerals, sugars, carbohydrates, proteins and lipids, *etc.* important for livestock nutrition. In spite the richness in nutritive compounds of studied groundnut hays, they can contain anti-nutritional substances (oxalates and phytates) that affect the preference, the ingestion and the digestibility and, therefore, the performances of the animals that ingest those[17]. Likewise, the presence of anti-nutritional compounds contents was reported in previous studies on several tree fodders[17].

The results found in the present survey demonstrate that groundnut hays in the Korhogo department of Korhogo are rich in nutrients. However, groundnut hays contain antinutrient substances (oxalates and phytates) that can affect the performances of the animals that ingest them if no treatment is done during the fattening rations. Genotype PA14 combined good hay yield with high hay nutritive quality. Their utilization will improve farmers' income and livelihoods in Côte d'Ivoire.

CONCLUSION

The present survey about the valorization of groundnut hays in animal feed showed that the five studied groundnut cultivars contain some nutrients such as macronutrients (sugars, proteins and lipids) and micronutrients such as mineral elements. Likewise, groundnut hays contain antinutrients substances abundantly that are oxalates and phytates. Consequently, the valorization of groundnut hays in livestock feed requires its previous treatment to eliminate the antinutrients (oxalates and phytates).

SIGNIFICANCE STATEMENT

This study discovers the possible use of groundnut hays to develop sheep and cattle fattening rations that will increase the food security of small-sized farms that can be beneficial for rural breeders. This study will help the researcher to uncover the alternative methods to make livestock fattening rations by substituting the partially or recommended groundnut hays basis on its nutriment contents that many researchers were not able to explore. The newly generated data about groundnut hays highlight both their significant nutritional potential and antinutrient contents. Thus, a new theory on the degradation of the antinutrient compounds before groundnut hays safe consumption by the livestock may be arrived at.

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