Sun-drying as an effective strategy to reduce total oxalate and phytate contents of plant leaves commonly used in quail feeding in Uganda

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Plant leaves are increasingly being integrated into poultry production systems in developing countries because leaves can reduce the proportion of the expensive conventional protein ingredients. Plant leaves are also good sources of minerals and carotenoid pigments for colouring broiler skins and egg yolks. In Uganda, leaves from plants including *Colocasia esculenta* (cocoyam), *Manihot esculenta* (cassava), *Amaranthus dubius* (amaranthus), *Brassica oleracea* (sukuma wiki) and *Ipomoea batatas* (sweet potato) are largely fed to quails in their fresh forms. However, minerals, particularly calcium and phosphorus of fresh plant leaves are biologically less available for absorption because of the presence of oxalates and phytates, which bind these minerals. Therefore, in this study, the effect of sun-drying on total oxalate and phytate contents of plant leaves commonly used in quail feeding in Uganda was determined. Samples of five most commonly used plant leaves in quail feeding were collected during the dry and wet seasons, and analysed for total oxalate and phytate compositions after sun-drying or oven-drying. Total oxalate and phytate contents were significantly lower ($P \leq 0.05$) in the sun-dried samples compared with the oven-dried samples. Overall mean oxalate contents were 71, 67, 64, 62, and 58% lower for sun-dried *Colocasia esculenta*, *Manihot esculenta*, *Ipomoea batatas*, *Brassica oleracea* and *Amaranthus dubius* leaves, respectively. For total phytate, the contents were 66, 19 and 9 % lower for sun-dried *Colocasia esculenta*, *Amaranthus dubius* and *Amaranthus dubius* leaves, respectively. Total oxalate and phytate contents were highest in *Brassica oleracea*, followed by *Colocasia esculenta* leaves, and lowest in *Amaranthus dubius* and *Ipomoea batatas* leaves. The contents ranged from 2.3 - 5.4 g/100g DM (total oxalates), and 12 - 68 mg/100g DM (total phytates). It was concluded that oxalate and phytate contents varied with plant type and that sun-drying is an effective processing technique for reducing total oxalates and phytates in plant leaves used to feed quails in Uganda.

Keywords: Chemical composition, oxalate, phytate, quail feeding, sun-drying

Plant leaves are increasingly being integrated in the feeding of poultry in the developing world (Oko 2010; Kanyinji and Zulu 2014). The leaves not only serve as cheap sources of crude protein but also provide some important minerals and carotenoid pigments, which enhance the yellow colour of broiler skins and egg yolks (Liu et al. 2008; Sadi et al. 2008). Five of the most commonly used plant leaves by quail farmers in Uganda are *Colocasia esculenta* (cocoyam), *Manihot esculenta* (cassava), *Amaranthus dubius* (amaranthus), *Brassica oleracea* (traditionally known as sukuma wiki) and *Ipomoea batatas* (sweet potato). These leaves are largely offered to quails in their fresh state (Nasaka et al. 2017). The fresh leaves of these plants are well accepted by poultry, and they are readily available throughout the year at little or no cost. However, plant leaves have been reported to contain oxalic acid and phytic acid, which form insoluble salts with mineral elements such as calcium and iron, and reduce their bioavailability (Oscarsson and Savage 2007; Hang et al. 2017).

Different processing techniques have been reported to effectively reduce the composition of these anti-nutritional factors; however, there are limitations to the use of some of the techniques. For example, boiling and ensiling were reported by Lumu and Katongole (2011) to reduce the oxalate composition of *Colocasia esculenta* leaves by 52.1 and 43.7%, respectively. However, boiling and ensiling may not be practical under resource-poor farm conditions because of irregular supply of energy

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(fuel) for cooking and lack of knowledge about the ensiling technique (Lumu and Katongole 2011). Furthermore, cooking or soaking have been reported to result in reduced levels of calcium composition in the processed materials as a result of leaching out of the soluble mineral elements as oxalate salts (Savage et al. 2000). It is therefore important to develop and adopt techniques that are affordable, practical for farmers and have no negative effect on mineral content. Sun-drying is therefore a suitable option worth exploring. Sun-drying plant leaves before feeding can be easily adopted under resource-poor farm conditions, and may be effective in reducing oxalate and phytate levels in plant leaves without negatively affecting their mineral compositions. However, there is limited information available on the effects of sun-drying on oxalate and phytate contents, particularly under different seasons. Therefore, this study was conducted to evaluate the effectiveness of sun-drying as a strategy for reducing total oxalates and phytates contents of commonly used plant leaves in quail feeding in Uganda.

Materials and methods

Source and collection of samples

The samples were obtained from 12 quail farms located in three urban districts of Uganda, namely Kampala, Mukono and Wakiso. For each district, four quail farms were purposively selected during the dry (mid-January to mid-February) and wet (mid-April to mid-May) seasons on the basis that the farms actively used plant leaves as a feed resource for quail production. This resulted in a total of 12 farms per season (four farms x three districts). Urban districts were selected because the majority of quail production in Uganda is done in these areas. Kampala is located 45 km north of the Equator at 0°34'N and 32°58'E, Mukono is located about 27 km east of Kampala at 0°28′N and 32°76′E, while Wakiso is located about 20 km west of Kampala at 0° 06’N and 32° 44′E.

Samples of *Amaranthus dubius*, *Manihot esculenta*, *Colocasia esculenta*, *Brassica oleracea* and *Ipomoea batatas* leaves were collected during the dry (mid-January to mid-February) and wet (mid-April to mid-May) seasons. For each district, two representative fresh samples of each leaf type were collected from each selected quail farm during the dry and wet seasons. This resulted in a total of 24 samples per plant leaf per season (two samples x four farms x three districts. At each quail farm, the samples (about 1 kg each) were taken from the freshly harvested materials for that day’s feeding. The samples were chopped into pieces (less than 2.5 cm), mixed thoroughly, placed in plastic bags, sealed, labeled and transported to the laboratory at Makerere University for further preparation.

Sample preparation

While at the laboratory, each of the collected samples was sub-divided into two portions of about 500 g each. One portion was oven-dried at 60°C for 24 hours in a forced-draught oven (oven-drying technique). The other portion was sun-dried by spreading out the materials under open-air sun for 7 - 8 hours until crisp dry (sun-drying technique). After drying (oven-drying and sun-drying), the samples were ground to pass through a 1 mm screen, and kept in airtight containers prior to analysis.

Chemical composition determination

The oven-dry samples were analysed for dry matter (DM), crude protein (CP), crude fiber (CF), calcium (Ca), phosphorous (P) and total ash according to AOAC (1990). Gross energy (GE) content was determined using a bomb calorimeter (Gallenkamp Autobomb, UK). Metabolisable energy (ME) was estimated as apparent metabolisable energy corrected for nitrogen (AME_n) using the prediction equation (R^2 = 0.97) proposed by Carré and Brillouet (1989) based on GE, CP and CF:

AME_n (kcal/kg DM) = 0.9362GE (kcal/kg DM) – 15.38CP (% DM) – 25.165CF (% DM).

Total oxalate analysis

The total oxalate contents of the oven and sun-dried samples were determined using the method outlined by Savage et al. (2000). Triplicate 0.5 g of each sample were placed in 100 ml flasks and total oxalates were extracted using 40 ml 0.2 Mol/L HCL at 80°C for 15 min. The extracts were allowed to cool and then transferred quantitatively into 100 ml volumetric flasks and made up to volume. The extracts were centrifuged at 2889 rcf for 15 min. The supernatant was filtered through a 0.45 mm paper filter. The chromatographic separation was carried out using a Rezex ROA 300 x 7.8 mm column (Phenomenex, Torrance, CA, USA) attached to a cation Hþ guard column (BioRad, Richmond, California, USA). The analytical column was held at 25°C. Data capture and processing were carried out using a peak simple chromatography data system (SSI Scientific Systems Inc, State College, PA, USA). The mobile phase used was an aqueous solution of 25 mm sulphuric acid. Samples (20 ml) were injected onto the column and eluted at a flow rate of 0.6 ml/min. The final oxalate values were converted to mg/100 g dry matter (DM) of the original material.

Total phytate analysis

Phytic acid was determined using the procedure described by Lolas and Markakis (1975). Triplicate 2 g of each sample were weighed into 250 ml conical flasks. 100 ml of 2% concentrated hydrochloric acid was used to soak each sample in the conical flask for 3 hours. This was then filtered through double-layered hard paper filters. 50 ml of each filtrate was then placed in 250 ml beakers with 107 ml of distilled water added to give proper acidity; 10 ml of 0.3% ammonium thiocyanate solution was added to each solution as an indicator. This was titrated with standard iron chloride solution, which contained 0.00195 g iron per ml. The end point was slightly brownish-yellow that persisted for 5 minutes. The percentage phytic acid was calculated using the following formula:

Phytic acid (%) = Y × 100
Where Y = titre value × 0.00195 g

Statistical analysis

All data were analysed using SAS version 9.1 (2003). Chemical composition was analysed using the PROC MIXED procedure according to the following model:

$$Y_{ijk} = \mu + S_i + F_{j(i)} + e_{ij}$$

Where: Y_{ij} = dependent variable (chemical composition); μ = overall mean effect; S_i = fixed effect of season (dry or wet); $F_{j(i)}$ = random effect of the sampling farm (source of the samples); and e_{ijk} = effect of the error term.

Oxalate and phytate compositions were analysed using the PROC MIXED procedure according to the following model:

$$Y_{ijk} = \mu + S_i + F_{j(i)} + D_k + SD_{ik} + e_{ijk}$$

Where: Y_{ijk} = dependent variable (total oxalate and phytate compositions); μ = overall mean effect; S_i = fixed effect of season (dry or wet); $F_{j(i)}$ = random effect of the sampling farm (source of the samples); D_k = fixed effect of drying technique (sun-drying or oven-drying); SD_{ik} = fixed effect of season × drying technique interaction; and e_{ijk} = effect of the error term. The fixed effects were considered significant when $P \leq 0.05$.

Results

Chemical composition

Table 1 shows the chemical compositions of the plant leaves in the dry and wet seasons. The content of DM was similar across the dry and wet seasons, except for *Ipomoea batatas* leaves, which had a significantly higher ($P \leq 0.05$) DM content in the dry season. The CP composition ranged from 22.1% DM (*Ipomoea batatas* leaves) to 31.3% DM (*Colocasia esculenta* leaves) in the dry season. There were no significant ($P > 0.05$) differences between the CP contents of the plant leaves between the dry and wet seasons, except for *Colocasia esculenta* leaves, which had significantly higher ($P \leq 0.05$) CP contents in the dry season. The CF content was lowest ($P \leq 0.05$) in *Ipomoea batatas* leaves (7.7% DM in the dry season) and highest ($P \leq 0.05$) in *Colocasia esculenta* leaves (14.0% DM in the dry season). The CF content in *Amaranthus dubius* and *Brassica oleracea* leaves was significantly higher ($P \leq 0.05$) during the dry season (12.1 and 13.6 % DM, respectively) than during the wet season (10.1 and 11.7 % DM, respectively). For *Ipomoea batatas* leaves, the CF content was significantly higher ($P \leq 0.05$) in the wet season.

Table 1: Chemical composition during the dry and wet seasons by plant leaf

	%	% DM					Kcal/kg DM
	DM	CP	CF	Ash	Ca	P	AME_n
Amaranthus dubius (amaranthus) leaves							
Dry season	29.0	27.9	12.1^a	18.0^a	2.49^a	0.827^a	2906
Wet season	24.1	27.1	10.1^b	14.5^b	2.12^b	0.566^b	2755
S.E.	2.75	1.23	0.827	1.21	0.234	0.090	126.7
P-value	0.128	0.526	0.002	0.007	0.010	0.002	0.243
Manihot esculenta (cassava) leaves							
Dry season	34.3	29.1	11.8	9.48	1.59^b	0.370^b	2894^b
Wet season	32.4	27.4	13.3	8.89	1.91^a	0.537^a	3549^a
S.E.	2.01	2.25	1.02	0.781	0.180	0.060	347.5
P-value	0.554	0.377	0.138	0.421	0.014	0.001	0.0006
Colocasia esculenta (cocoyam) leaves							
Dry season	21.3	31.3^a	14.0	14.1^a	2.22	0.393^b	3355^a
Wet season	18.3	24.1^b	13.5	12.3^b	2.07	0.635^a	2247^b
S.E.	2.31	1.55	0.670	0.619	0.232	0.060	271.8
P-value	0.373	<0.0001	0.362	0.002	0.072	0.002	<0.0001
Brassica oleracea (sukuma wiki) leaves							
Dry season	16.9	24.1	13.6^a	20.2	2.04	0.440	2825^a
Wet season	17.0	26.1	11.7^b	16.8	2.64	0.465	2378^b
S.E.	2.88	0.713	0.548	1.16	0.534	0.114	112.2
P-value	0.979	0.080	0.012	0.075	0.165	0.772	0.021
Ipomoea batatas (sweet potato) leaves							
Dry season	29.4^a	22.1	7.7^b	11.5^a	1.83	0.330^b	3479^a
Wet season	22.6^b	24.8	11.0^a	10.5^b	1.99	0.562^a	2001^b
S.E.	1.75	2.71	1.52	0.468	0.316	0.046	328.1
P-value	0.016	0.193	0.0008	0.048	0.656	<0.0001	<0.0001

[ab]Means in the same column with different superscripts significantly differ at $P \leq 0.05$

DM = Dry Matter; CP = Crude Protein; CF = Crude Fiber; Ca = Calcium; P = Phosphorous and AME_n = Apparent Metabolisable Energy corrected for nitrogen

Amaranthus dubius, *Colocasia esculenta* and *Ipomoea batatas* leaves had significantly higher ($P \leq 0.05$) ash contents in the dry (18.0, 14.1 and 11.5 % DM, respectively) than in the wet season (14.5, 12.3 and 10.5 % DM, respectively). The Ca content significantly differed ($P \leq 0.05$) between the two seasons only in *Amaranthus dubius* and *Manihot esculenta* leaves. For *Amaranthus dubius* leaves, Ca content was significantly higher ($P \leq 0.05$) in the dry season yet for *Manihot esculenta* leaves the Ca content was significantly higher ($P \leq 0.05$) in the wet season (2.49 and 1.91 % DM, respectively). The P contents of the plant leaves significantly differed ($P \leq 0.05$) between the two seasons, except for *Brassica oleracea* leaves. The P content in *Amaranthus dubius* leaves was significantly higher ($P \leq 0.05$) in the dry season. However, for *Manihot esculenta*, *Colocasia esculenta* and *Ipomoea batatas leaves*, the P content was significantly higher ($P \leq 0.05$) in the wet season.

The energy content of the plant leaves significantly differed ($P \leq 0.05$) between the two seasons, except for *Amaranthus dubius* leaves. The dry season samples had significantly higher ($P \leq 0.05$) energy values for *Colocasia esculenta*, *Brassica oleracea and Ipomoea batatas* leaves, except for *Manihot esculenta* leaves, which had a higher energy content in the wet season.

Total oxalate content

The plant leaves significantly differed ($P \leq 0.05$) in total oxalate content in both dry and wet seasons (Table 2). *Brassica oleracea* and *Colocasia esculenta* leaves had the highest ($P \leq 0.05$) total oxalate contents both in the dry (5.4 and 4.2 g/100g DM, respectively) and wet (4.3 and 3.8 g/100g DM, respectively) seasons. *Ipomoea batatas* and *Amaranthus dubius* leaves had the lowest ($P \leq 0.05$) total oxalate contents both in the dry (3.0 and 3.1 g/100g DM, respectively) and wet (2.3 and 3.1 g/100g DM, respectively) seasons. Total oxalate contents were significantly lower ($P \leq 0.05$) in the sun-dried samples compared with the oven-dried samples. Overall mean oxalate contents were 71, 67, 64, 62, and 58% lower for sun-dried *Colocasia esculenta*, *Manihot esculenta*, *Ipomoea batatas*, *Brassica oleracea* and *Amaranthus dubius* leaves, respectively, than their oven-dried counterparts. The plant leaf type × drying technique interaction effect on total oxalate content was significant ($P \leq 0.05$) for all the plant leaves in both the dry and the wet seasons.

Table 2: Total oxalate and phytate compositions of oven-dried and sun-dried plant leaves by season

Plant leaf	*Amaranthus dubius*		*Manihot esculenta*		*Colocasia esculenta*		*Brassica oleracea*		*Ipomoea batatas*			P-value		
Drying technique	Oven	Sun	Oven	Sun	Oven	Sun	Oven	Sun	Oven	Sun	S.E.	L	D	L × D
Dry season														
Total oxalate, g/100 g	3.1^{d}	1.3^{f}	3.7^{c}	1.2^{fg}	4.2^{b}	1.2^{fg}	5.4^{a}	2.0^{e}	3.0^{d}	1.0^{g}	0.11	<0.0001	<0.0001	<0.0001
Total phytate, mg/100 g	14^{i}	13^{j}	16^{h}	21^{g}	68^{a}	23^{f}	32^{c}	33^{b}	27^{d}	24^{e}	0.538	<0.0001	<0.0001	<0.0001
Wet season														
Total oxalate, g/100 g	3.1^{c}	1.3^{f}	3.3^{c}	1.1^{g}	3.8^{b}	1.1^{g}	4.3^{a}	1.7^{e}	2.3^{d}	0.9^{g}	0.09	<0.0001	<0.0001	<0.0001
Total phytate, mg/100 g	17^{e}	12^{f}	15^{ef}	25^{cd}	67^{a}	23^{d}	32^{b}	32^{b}	27^{c}	25^{cd}	1.51	<0.0001	<0.0001	<0.0001

[abcdefghij] Means in the same row with different superscripts significantly differ at $P \leq 0.05$

L = plant leaf; D = drying technique used on the leaves; L x D = the plant leaf (L) and drying technique (D) interaction

Total phytate content

The plant leaves significantly differed (P ≤ 0.05) in total phytate content in both dry and wet seasons (Table 2). *Colocasia esculenta* and *Brassica oleracea* leaves had the highest (P ≤ 0.05) total phytate contents both in the dry (68 and 32 mg/100g DM, respectively) and wet (67 and 32 mg/100g DM, respectively) seasons. *Amaranthus dubius* and *Manihot esculenta* leaves had the lowest (P ≤ 0.05) total phytate contents both in the dry (14 and 16 mg/100g DM, respectively) and wet (17 and 15 mg/100g DM, respectively) seasons. Total phytate contents were significantly lower (P ≤ 0.05) in the sun-dried samples compared with the oven-dried samples, except for *Manihot esculenta* and *Brassica oleracea* leaves, which had similar (P > 0.05) contents across the two seasons. Overall mean phytate contents were 66, 19 and 9% lower for sun-dried *Colocasia esculenta*, *Amaranthus dubius* and *Amaranthus dubius* leaves, respectively, than their oven-dried counterparts. The plant leaf type × drying technique interaction effect on total phytate content was significant (P ≤ 0.05) for all the plant leaves in both the dry and the wet seasons.

Discussion

Chemical composition

The CP values observed in this study were within the range of those previously reported (Lumu and Katongole 2011; Apata and Babalola 2012; Ngugi et al. 2017). The present study confirmed earlier reports that these five plant leaves are rich sources of CP (Martens et al. 2012; Alikwe and Owen 2014). Since DM content was not different, the higher CP contents observed in the dry season for *Colocasia esculenta* leaves could be because *Colocasia esculenta* grows in areas with high moisture content, its nutritional profile is less influenced by growing season.

The observed higher CF contents during the dry season for Brassica oleracea leaves are consistent with previous observations of rapid cell wall accumulation during the dry season (Aderinola et al. 2007). The higher CF contents observed during the wet season for Manihot esculenta and Ipomoea batatas leaves could possibly be explained by the influence of stage of maturity, since it is common knowledge that fibre in most plants increases as the plant matures. Like other plant leaves, the leaves analysed in this study were low in metabolisable energy which points to the potentially low soluble carbohydrates, such as starch, found in these plants (Navarro et al. 2019).

The observation that ash contents were significantly higher in the dry season for *Amaranthus dubius*, *Colocasia esculenta*, and *Ipomoea batatas* leaves as well as a tendency for higher ash content in the dry season for *Brassica oleracea* leaves reaffirms previous reports of the effects of organic matter loss (due to drought stress in the dry season) and contamination with soil particles on ash quantity in herbaceous biomass (Bakker and Elbersen 2005). During conditions of drought stress, there is often an enhanced allocation of organic matter to the roots, which leads to increased total ash content in other plant parts, particularly in leaves (Leport et al. 2006; Farooq et al. 2009).

The average calcium and phosphorus values observed for the plant leaves in the present study were high and within the ranges reported by Bakker and Elbersen (2005) in herbaceous biomass. The high calcium and phosphorous contents observed in the plant leaves would prevent the poor eggshell quality problem associated with the use of diets low in calcium and phosphorus contents, since calcium and phosphorous are among the primary factors that affect eggshell quality (Attia 2014). The higher calcium content during the dry season for *Amaranthus dubius* and *Colocasia esculenta* leaves could be attributed to the relatively older leaves present on these plants during this time of year since retranslocation of calcium from old leaves to new leaves is not as rapid in the dry season. Generally, these plant leaves contained higher phosphorus contents during the wet season, which could also be attributed to the stage of maturity of these leaves. Zhang et al. (2013) previously reported that leaf phosphorus content is a function of age, which decreases as the leaves become older.

Total oxalate composition

The total oxalate contents reported in this study for *Amaranthus dubius, Colocasia esculenta* and *Ipomoea batatas* leaves were within the range of earlier reports (Mizray et al. 2001; Lumu and Katongole 2011; Mwanri et al. 2011). However, the contents reported for *Manihot esculenta* and *Brassica oleracea* leaves were higher by 58% and 57%, respectively, than those reported by Wobeto et al. (2007) and Edorgan and Onar (2012). These differences can be attributed to species, agro-ecological conditions, and variations in analytical methods. All the studied plant leaves contained more than 0.1 g/100g of total oxalates, which is an indication for high total oxalates concentration (Judprasong et al. 2006). Ingestion of feedstuffs with total oxalates exceeding 0.1 g/100g is of concern in quail nutrition since oxalates affect the animals' metabolism of minerals, such as calcium and iron (Thakur et al. 2019). Oxalic acid binds calcium and forms calcium oxalate, which is insoluble, and basically not available for absorption and assimilation. Unsurprisingly, *Brassica oleracea* leaves had the highest content of total oxalate in this study. *Brassica oleracea* leaves have been recently reported to be a rich source of oxalates (Satheesh and Workneh Fanta 2020).

The observation that overall mean oxalate contents were 71, 67, 64, 62, and 58% lower for sun-dried *Colocasia esculenta*, *Manihot esculenta*, *Ipomoea batatas*, *Brassica oleracea* and *Amaranthus dubius* leaves, respectively, could be attributed to the fraction of soluble oxalates relative to total oxalates. Oxalates can be found as soluble (oxalates of potassium, sodium, magnesium, and ammonium) and insoluble (oxalates of calcium and iron) forms in plants (Poeydomenge and Savage 2007). Danso et al. (2009) reported reduced total oxalate contents of plant leaves on sun-drying (25 - 37°C). Loss of the soluble oxalate fraction as moisture evaporates from the harvested leaves is the most likely cause of the reduced oxalate contents with sun-drying. The soluble proportion of oxalates in *Colocasia esculenta* leaves has been reported to be 74% of the total oxalate (Oscarsson and Savage 2007). On the other hand, *Amaranthus* leaves have been reported to contain less than 10% soluble oxalates (Radek and Savage 2008; Onyango et al. 2012), while *Brassica oleracea* and *Ipomoea batatas* leaves have been reported to contain about 50% soluble oxalates (Mwanri et al. 2011; Kasimala et al. 2018). The higher the percentage of soluble oxalates in plant leaves, the higher the reduction in total oxalate content of the plant leaves.

In this study, the total oxalate contents of the plant leaves were about 6 - 21% higher for the dry season compared with the wet season. Other studies (Rahman et al. 2006; Rahman and Kawamura 2011; Umami et al. 2018) have attributed the varying oxalate contents of plant leaves to the influence of growing season. Growing season influence is explained by the differences in the concentration of calcium oxalate crystals. John (1990) observed that calcium oxalate crystals occur at the termination of growth periods (a distinguishing feature of the dry-season), while Gourlay and Grime (1994) reported that calcium oxalate crystals appeared to increase in quantity with the dryness of the site (another key distinguishing feature of the dry-season).

Total phytate composition

The average total phytate composition reported in this study for *Amaranthus dubius* and *Manihot esculenta* leaves was within the range reported by Adepoju and Olodu (2016). However, the composition observed for *Colocasia esculenta*, *Brassica oleracea* and *Ipomoea batatas* leaves was higher than in previous studies. For example, Adepoju and Olodu (2016) and Ukom and Obi (2018) reported phytate contents of 18.97, 0.47 and 1.44 mg/100g for *Colocasia esculenta*, *Brassica oleracea* and *Ipomoea batatas* leaves, respectively; values that are over 70% lower than those observed in this study. The high phytate composition of *Colocasia esculenta*, *Brassica oleracea* and *Ipomoea batatas* in this study may be attributed to the differences in variety of the plants, agro-ecological conditions, and method of analysis. Like oxalates, phytates also chelate and make un-absorbable mineral complexes with phosphorus, zinc, iron, calcium and magnesium thereby reducing their bio-availability (Nguyen 2012; Nyonje 2015).

Generally, sun-drying reduced the total phytate contents with sun-dried *Colocasia esculenta*, *Amaranthus dubius* and *Amaranthus dubius* leaves being 66, 19 and 9 %, respectively, lower than their oven-dried counterparts. Similar observations after sun-drying have been reported by Ademiliyu et al. (2018) and Danso et al. (2019). Sun-drying leads to leaching due to vaporisation, which results in reduced phytate content, while oven-drying may tend to concentrate the phytates in the leaves (Ademiliyu et al. 2018).

Conclusion

All the five plant leaves analysed in this study contained high CP contents during both the dry and wet seasons. The total oxalate and phytate contents differed among the plant leaves in both seasons; with *Brassica oleracea* and *Colocasia esculenta* leaves having the highest values for both total oxalate and phytate. The oxalate and phytate contents in plant leaves commonly used in Uganda exceeded the threshold reported for quail farming. Sun-dried *Colocasia esculenta*, *Manihot esculenta*, *Ipomoea batatas*, *Brassica oleracea* and *Amaranthus dubius* leaves, respectively, had total oxalate contents lower by 71, 67, 64, 62, and 58% than their oven-dried counterparts. For total phytate, the contents were 66, 19 and 9% lower for sun-dried *Colocasia esculenta*, *Amaranthus dubius* and *Amaranthus dubius* leaves, respectively. These results indicated that sun-drying is an effective processing technique to reduce oxalate and phytate contents within tolerable limits. Further studies are recommended to determine the optimum inclusion levels of sun-dried meals of these plant leaves in quail diets.

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