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Feedstuffs potential of harvest by-products from two oleaginous cucurbits

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Among the generated crop residues and by-products in tropical agriculture, those of cucurbits represent great opportunities for animal nutrition. Nutritive profile of harvest by-products (dried leaves, fermented fruits, non fermented fruits and seeds shells) of two oleaginous cucurbits (*Citrullus lanatus* and *Lagenaria siceraria*) were investigated in order to explore their potential use as feedstuffs. The moisture, ash, and crude fibres contents were 4.81 to 12.87, 9.93 to 18.29, and 2.18 to 16.35%, respectively. Shells of *L. siceraria* seeds yielded the highest carbohydrate content (84.80 ± 2.78 %) while the highest calorific value (380.92 ± 11.40 kcal/100 g) was obtained in *C. lanatus* bebu. The contents of threonine (Thr), lysine (Lys) and methionine (Met) in dried leaves of *C. lanatus* bebu were 4.16, 6.86 and 6.89 g/100 g proteins, respectively. The content of methionine (Met) was 5.81 g/100 g proteins in fermented fruits of *C. lanatus* (wlêwlê). The harvest by-products analyzed in this study contained remarkably high amounts of potassium (671.78 – 4738.79 mg/100 g) and calcium (342.08 – 2963.95 mg/100 g) with highest value (4738.79 ± 230.10; 2963.95 ± 135.74 mg/100 g) for non-fermented fruits of *L. siceraria* and dried leaves of *C. lanatus* wlêwlê, respectively. The analyzed plants parts were also notable sources of magnesium, ranging from 221.45 ± 1.96 mg/100 g (non-fermented fruits of *L. siceraria*) to 872.10 ± 48.49 mg/100 g (dried leaves of *C. lanatus* wlêwlê). All these results suggest that the studied by-products could be used as valuable feedstuffs.

Key words: Harvest by-products, nutritive value, cucurbits, feedstuffs.

INTRODUCTION

Shortages of feed resources often impose major constraints on the development of animal production in tropical zones (Aregheore, 2000). In most developing countries, considerable quantities of by-products and crop residues generated every year and tending to accumulate can be utilized as feedstuffs (Ensminger et al., 1990). A by-product

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feedstuff is a product that has value as an animal feed and is obtained during the harvesting or processing of a commodity in which human food or fibre is derived (Fadel, 1999).

Among the generated crop residues and by-products in tropical agriculture, those of cucurbits have a great economical importance (Dupriez and De Leener, 1987; Pitrat et al., 1999). Cucurbits belonging to the family Cucurbitaceae have common features: large leaves, creeping or climbing stems with simple or branched tendrils, and fleshy fruits containing numerous seeds (Ajuru and Okoli, 2013). Considering their consumption mode, two major groups are distinguished: those with edible flesh (watermelon, melon, squash, etc.) and those with oleaginous seeds (bitter cucumber, African melon, pumpkin, etc.) which are consumed as soup thickeners or cakes (Zoro Bi et al., 2003). Cucurbits cultivated for seed consumption are well adapted to extremely divergent agro-ecosystems and various cropping systems characterized by minimal inputs (Yaniv et al., 1999; Besognin, 2002).

Citrullus lanatus (Thunberg) Matsumura & Nakai, and *Lagenaria siceraria* (Molina) Standley are among the most widely cultivated oilseed cucurbits in tropical zones (Levi et al., 2001, 2009; Zoro Bi et al., 2006; Dane and Liu, 2007; Sarao et al., 2014). *C. lanatus* is a monoecious species, yellow flowered, and creeping annual vine, presenting leaves deeply divided into 5-7 more or less subdivided lobes. The fruits are round or oval, uniformly light green or mottled light and dark green and contain a white bitter flesh embedding about 200 seeds. Based on the morphology of seeds, two distinct cultigroups have been described (Zoro Bi et al., 2006). The first one, “wlêwlê”, is characterized by glossy seeds with a tapered proximal extremity. Within the second cultigroup, “bebu”, seeds are heavier and have a flat ovoid shape with rugged and thick ends (Zoro Bi et al., 2003). *L. siceraria* is also a monoecious species but white-flowered. Fruit and seeds shape and size are reported to be highly variable in the genus *Lagenaria* (Besognin, 2002). There are two varieties in *L. siceraria*, which are distinguishable by the hardness of their fruit exocarp and seed tegument. The variety with hard-shelled fruit and inedible seed is mainly cultivated for its dry fruit that is used mostly as containers, musical instruments, fishing floats, etc. The immature and tender fruits of some forms of this variety are also eaten as vegetable in some communities. The variety with soft-shelled fruit produces oleaginous edible seeds. The seeds of this variety are extracted after a 7-day fermentation period of cut fruit containing a juicy pulp to which they are attached (Zoro Bi et al., 2003). This process is expected to facilitate the seed separation from the surrounding tissues, and increase their nutritive value and germination percentage (Achinewhu and Ryley, 1986).

Many studies on physicochemical and nutritive characteristics of cucurbit seeds have revealed that they are rich in minerals (calcium, potassium, phosphorus, iron, magnesium and zinc), proteins (36%) and fats (50%) (Achu et al., 2005; Loukou et al., 2011). In addition, oils extracted from cucurbit seeds contain relatively high content of essential fatty acid, particularly linoleic acid and this property made them recommended for healthy human nutrition (Achu et al., 2005; Anhwange et al., 2010).

Data from agro-ecological, cultural, genetic, and nutriational investigations (Pitrat et al., 1999; Yaniv et al., 1999; Besognin, 2002; Zoro Bi et al., 2006; Dane and Liu, 2007; Fuller et al., 2010; Loukou et al., 2011; Sarao et al., 2014) suggest that the oleaginous forms of *C. lanatus* and *L. siceraria* have a potential to play crussial roles in the improvement of food security in tropics, particularly though helping the poor for subsistence and income, reducing risks of over-reliance on major crops, increasing agriculture sustainability by mean of reduction in inputs, and contributing to food quality (Frison et al., 2011; Mayes et al., 2012). Despite these potentialities, these cucurbits are somehow neglected and classified as minor crops. Furthermore, there is a lack of scientific data concerning nutritive profile of some harvest by-products, derived from cucurbits, such as dried leaves, dried fruits, dried fermented fruits and seed shells. The study was undertaken to promote the harvest by-products from the oleaginous forms of *C. lanatus* and *L. siceraria* by exploring their nutritive profile for their potential use as feedstuffs.

MATERIALS AND METHODS

Plant material

Fruits and leaves of two edible-seeded cucurbit species, namely two cultivars of *C. lanatus* (wlêwlê and bebu) and a soft-shelled *L. siceraria* were harvested at maturity on May 2012 from an experimental farmland (15 m × 10 m) located at Anyama (longitudes 4°03′52.7″-4°03′53.9″ W; latitudes 5°29′54.4″-5°29′54.6″ N), a suburb of Abidjan (Côte d’Ivoire). The collected plant parts were washed with distilled water, drained at ambient temperature and subjected to processing.

Processing methods

Fruits and leaves of the studied cucurbits were processed as depicted in Figure 1. The leaves were sun-dried on clean papers for 10 days with constant turning over to avert fungal growth. The fruits containing seeds were entirely cut up using a stainless steel laboratory knife. The pieces obtained were divided into two lots. The first lot was packaged in sterile airtight polythene bags and allowed to ferment for 7 days in the darkness. Afterwards, the fermented pieces of fruits were oven-dried (Memmert, Germany) at 50°C for 7 days. The seeds of fermented fruits were removed, sun-dried for 3 days, sorted to remove bad ones and manually shelled. The second lot was immediately oven-dried at 50°C for 7 days.

The dried materials (leaves, fermented fruits, non-fermented fruits and shells) obtained were ground with a laboratory crusher (Culatti, France) equipped with a 10 µm mesh sieve. The powdered samples obtained were stored in airtight polythene bags at 4 °C

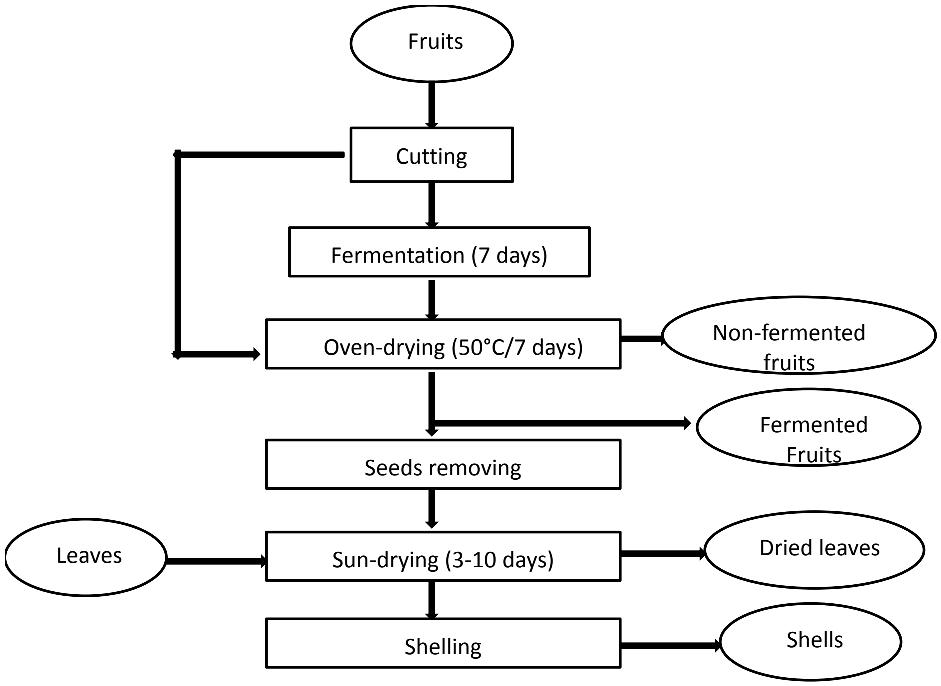

Figure 1. Processing diagram of fruits and leaves from *C. lanatus* and *L. siceraria.*

until further analyses. Three replicates were performed for each selected by-product.

Physicochemical analysis

Proximate analysis

Moisture, ash, proteins and lipids were determined using AOAC (1990) official methods. For crude fibres, 2 g of dried powdered sample were digested with 0.25 M sulphuric acid and 0.3 M sodium hydroxide solution. The insoluble residue obtained was washed with hot water and dried in an oven (Memmert, Germany) at 100°C until constant weight. The dried residue was then incinerated, and weighed for the determination of crude fibres content. Carbohydrates and calorific value were calculated using the following formulas (WHO/FAO, 1985):

Carbohydrates = 100 – (% moisture + % proteins + % lipids + % ash + % fibres)

Calorific value = (% proteins x 4) + (% carbohydrates x 4) + (% lipids x 9)

Polyphenols content was determined using the method reported by Singleton et al. (1999). A dried powdered sample (1 g) was soaked in 10 mL of methanol 70% (w/v) and centrifuged at 1000 rpm for 10 min. An aliquot (1 mL) of supernatant was oxidized with 1 mL of Folin–Ciocalteu's reagent and neutralized by 1 mL of 20% (w/v) sodium carbonate. The reaction mixture was incubated for 30 min at ambient temperature and absorbance was measured at 745 nm using a spectrophotometer (PG Instruments, England). The polyphenols content was obtained using a calibration curve of gallic acid (1 mg/mL) as standard.

Amino-acids analysis

Free amino acids were extracted from 5 g dry matter with 20 mL sodium citrate 0.2 N, pH 2.3 and protein hydrolysis was performed with hydrochloric acid 6 N at 110°C for 24 h. After evaporation, the aliquots were re-suspended in sodium borate buffer 0.4 N, pH 9.5. The homogenized mixture was filtered through a 0.45 mm Millipore membrane (Sartorius AG, Goettingen, UK). The extracts obtained were stored at -20°C until HPLC analysis. An aliquot of 20 µL of filtered sample was injected for HPLC analysis after derivatisation of the amino acids on a pre-column with orthophtaldialdehyde. The HPLC equipment was composed of a pump (Shimadzu LC-6A Liquid Chromatograph), an UV detector (Shimadzu SPD-6A UV spectrophotometry detector) and an integrator (Shimadzu CR 6A Chromatopac). Chromatographic separation of amino acids was performed with an ion exclusion column Hypersil C_8 (25 cm x 4.6 mm x 5 µm, Interchom, France) maintained at 35°C. The mobile phase was a buffer solution of phosphate/methanol (88:12, v/v) with a flow rate of 0.6 mL/min and the detector was set at 280 nm. The standards were filtered and injected separately and each analysis was performed in triplicate. Amino acids were identified and quantified by comparison of their retention time and peak area with those of standard solutions.

Mineral analysis

The mineral content was estimated by dry ashing of dried powdered sample (5 g) in a muffle furnace (Pyrolabo, France). The ash obtained was dissolved in 5 mL of HCl/HNO_3 and analyzed using the atomic absorption spectrophotometer (AAS model, SP9).

Statistical analysis

All the analyses were performed in triplicate and data were analyzed using SPSS 11.5. Values were expressed as mean ± standard deviation (SD). Treatments (species and processing methods) were compared using two-way analysis of variance (ANOVA2). Differences between means were evaluated by Duncan's test. Statistical significant difference was stated at $p < 0.05$.

Table 1. Physicochemical characteristics of harvest by-products from *C. lanatus* (wlêwlê and bebu) and *L. siceraria.*

Cucurbit	By-product	Moisture (%)	Ash (%)	Fibres (%)	Polyphenols (mg/100 g)	Lipids (%)	Proteins (%)	Carbohydrates (%)	Calorific value (kcal/100 g)
***C. lanatus* (wlêwlê)**	DL	11.72±0.27^{b}	17.00±0.20^{bc}	13.38±0.46^{de}	428.82±3.18^{b}	3.61±0.16^{bc}	6.79±0.00^{a}	62.09±4.88^{c}	307.87±19.70^{bcd}
	FF	9.42±0.13^{d}	16.27±1.17^{c}	16.05±0.26^{a}	166.60±3.38^{h}	1.50±0.09^{g}	2.44±0.14^{g}	66.13±5.25^{bc}	287.78±20.52^{cd}
	NFF	9.50±0.33^{d}	16.93±0.30^{bc}	14.16±0.72^{cd}	230.76±3.97^{g}	1.50±0.16^{g}	3.65±0.22^{d}	66.86±4.71^{bc}	295.58±18.55^{bcd}
	S	11.60±1.04^{b}	9.93±0.32^{e}	3.18±0.52^{f}	89.32±0.92^{i}	3.99±0.28^{b}	4.35±0.00^{c}	66.86±4.71^{bc}	374.21±11.73^{a}
***C. lanatus* (bebu)**	DL	10.43±1.12^{c}	16.93±8.55^{bc}	13.05±0.48^{e}	265.34±7.62^{f}	1.23±0.10^{g}	6.37±0.12^{b}	65.00±5.28^{c}	296.40±20.58^{bcd}
	FF	9.62±0.14^{d}	17.45±0.43^{ab}	16.35±0.09^{a}	361.37±6.29^{e}	2.27±0.12^{f}	2.93±0.00^{f}	63.95±5.09^{c}	287.92±20.01^{cd}
	NFF	8.39±0,27^{e}	13.07±0.90^{d}	14.47±0.55^{c}	389.21±0.68^{c}	3.36±0.22^{cd}	3.11±0.08^{f}	68.72±3.37^{bc}	317.48±13.70^{b}
	S	12.87±0.15^{a}	10.13±0.21^{e}	2.78±0.46^{fg}	91.84±4.04^{i}	5.00±0.32^{a}	1.76±0.08^{i}	82.21±2.80^{a}	380.92±11.40^{a}
L. siceraria	DL	10.70±0.35^{c}	17.47±0.42^{ab}	14.32±0.06^{c}	396.08±5.20^{c}	2.68±0.20^{ef}	6.75±0.26^{a}	61.53±5.44^{c}	297.05±20.75^{bcd}
	FF	9.60±0.13^{c}	18.29±0.31^{a}	15.68±0.92^{ab}	379.02±5.25^{d}	1.58±0.17^{g}	3.41±0.08^{e}	64.45±4.98^{c}	285.86±20.14^{d}
	NFF	4.81±0.16^{f}	10.33±0.31^{e}	14.92±0.29^{bc}	443.25±1.51^{a}	1.71±0.48^{g}	2.05±0.00^{h}	72.78±2.96^{b}	315.88±10.74^{bc}
	S	11.70±0.05^{b}	10.03±0.15^{e}	2.18±0.45^{g}	54.68±3.98^{j}	1.89±0.68^{de}	1.96±0.00^{h}	84.80±2.78^{a}	372.75±11.83^{a}

Data are represented as means ± SD (n = 3). Means in the columns with no common superscript differ significantly ($p < 0.05$). DL, dried leaves; FF, fermented fruits; NFF, non-fermented fruits; S, shells.

RESULTS

Physicochemical properties

The proximate composition of harvest by-products (leaves, fruits and shells) from *C. lanatus* and *L. siceraria* is presented in Table 1. The physico-chemical parameters generally differed significantly ($p < 0.05$) among species. Moisture of all samples varied from 4.81 to 12.87%. The ash content ranged from 9.93 ± 0.32% (shells of *C. lanatus* wlêwlê seeds) to 18.29 ± 0.31% (fermented fruits of *L. siceraria*). There was a significant variation in the fibres content of the plant parts examined, ranging from 2.18 ± 0.45% (shells of *L. siceraria* seeds) to 16.35 ± 0.09% (fermented fruits of *C. lanatus* bebu). The fat content of the remaining plant parts was in the range 1.23 - 5%. Proteins content ranged from 1.76 ± 0.08% (shells of *C. lanatus* bebu seeds) to 6.79 ± 0.00% (*C. lanatus* wlêwlê dried leaves). Shells of *L. siceraria* seeds showed the highest carbohydrate content (84.80 ± 2.78%) while the highest calorific value (380.92 ± 11.40 kcal/100 g) was obtained with *C. lanatus* bebu. The analysis of polyphenols revealed that non-fermented fruits of *L. siceraria*, dried leaves of *C. lanatus* wlêwlê, and dried leaves of *L. siceraria* were major sources with contents of 443.25 ± 1.51, 428.82 ± 3.18, and 396.08 ± 5.20 mg/100 g, respectively.

Amino acid composition

The amino acids contents of leaves, fruits, and shells from *C. lanatus* and *L. siceraria* are presented in Table 2. Seven major amino acids, namely threonine (Thr), proline (Pro), serine (Ser), Tyrosine (Tyr), methionine (Met), lysine (Lys), and cystine (Cyst) were determined. The contents of these amino acids differed significantly ($p < 0.05$) and ranged from 0.045 to 6.89 g/100 g proteins. The contents of Thr, Lys, and Met in dried leaves of *C. lanatus* bebu were 4.16, 6.86, and 6.89 g/100 g proteins, respectively. The content of Met was 5.81 g/100 g proteins in fermented fruits of *C. lanatus* (wlêwlê).

Mineral composition

Mean values for mineral content of analyzed samples are presented in Table 3. The harvest by-products analyzed in this study contained remarkably high amounts of potassium (671.78 – 4738.79 mg/100 g) and calcium (342.08 – 2963.95 mg/100 g) with the highest values (4738.79 ± 230.10;

Table 2. Amino-acids composition (g/100g proteins) of harvest by-products from *C. lanatus* (wlêwlê and bebu) and *L. siceraria.*

Cucurbit	By-product	Thr	Pro	Ser	Tyr	Met	Lys	Cyst
C. lanatus **(wlêwlê)**	DL	3.99±0.02^{b}	3.60±0.00^{b}	1.27±0.00^{b}	0.44±0.00^{d}	6.61±0.00^{a}	4.07±0.01^{b}	0.90±0.01^{c}
	FF	0.94±0.01^{d}	2.84±0.01^{c}	0.53±0.00^{e}	nd	5.81±0.02^{b}	1.26±0.05^{c}	nd
	NFF	nd	nd	0.12±0.05^{f}	nd	2.28±0.05^{d}	nd	nd
	S	0.10±0.00^{g}	0.49±0.01^{e}	nd	nd	0.96±0.01^{e}	0.31±0.00^{e}	nd
C. lanatus **(bebu)**	DL	4.16±0.01^{a}	6.01±0.05^{a}	5.83±0.03^{a}	1.82±0.01^{a}	6.89±0.05^{a}	6.86±0.00^{a}	6.27±0.03^{a}
	FF	0.51±0.01^{e}	5.83±0.04^{a}	0.64±0.00^{e}	0.51±0.00^{c}	2.47±0.01^{d}	1.40±0.00^{c}	0.85±0.01^{c}
	NFF	nd	nd	0.61±0.01^{e}	0.68±0.09^{c}	2.45±0.05^{d}	nd	0.71±0.01^{d}
	S	nd	nd	nd	0.86±0.06^{b}	nd	1.11±0.03^{d}	nd
L. siceraria	DL	3.65±0.02^{b}	0.87±0.03^{d}	1.39±0.03^{b}	0.07±0.00^{e}	4.23±0.01^{c}	1.33±0.05^{c}	1.23±0.01^{b}
	FF	1.98±0.01^{c}	0.49±0.03^{e}	1.07±0.01^{c}	nd	2.74±0.06^{d}	nd	0.76±0.01^{d}
	NFF	0.38±0.00^{f}	0.22±0.00^{f}	0.045±0.00^{g}	nd	0.99±0.01^{e}	nd	nd
	S	0.34±0.00^{f}	nd	0.80±0.00^{d}	nd	nd	nd	nd

Data are represented as means ± SD (n = 3). Means in the columns with no common superscript differ significantly ($p < 0.05$). **DL**, dried leaves; **FF**, fermented fruits; **NFF**, non-fermented fruits; **S**, shells; dw, dry weight; nd, non-detected. Thr , Threonine ; Pro, proline; Ser, serine ; Tyr, tyrosine; Lys ,lysine; Met , methionine; Lys, lysine; Cyst, cystine.

Table 3. Mineral composition (mg/100g dw) of harvest by-products from *C. lanatus* (wlêwlê and bebu) and *L. siceraria.*

Cucurbit	By-product	Na	Mg	P	K	Ca	Fe	Zn	Cu
C. lanatus **(wlêwle)**	DL	nd	872.10±48.49^{a}	510.57±30.56^{ef}	1017.17±54.51^{g}	2963.95±135.7^{a}	117.02±17.20^{ef}	nd	31.73±3.83^{abc}
	FF	nd	349.32±26.44^{g}	443.90±27.32^{fg}	1325.46±92.00^{f}	775.87±60.17^{e}	566.66±28.94^{b}	14.63±12.67^{a}	nd
	NFF	nd	570.60±20.82^{e}	624.52±62.61^{cd}	1885.27±100.5^{e}	1479.43±81.39^{d}	583.87±86.98^{b}	nd	38.68±3.42^{ab}
	S	29.82±1.79^{b}	288.43±7.64^{h}	769.69±23.84^{b}	671.78±7.74^{h}	419.47±1.49^{gh}	352.20±17.81^{d}	nd	16.90±7.81^{cd}
C. lanatus **(bebu)**	DL	nd	810.30±34.03^{b}	437.90±23.76^{g}	988.17±18.29^{g}	1494.67±86.80^{cd}	373.81±13.80^{d}	nd	38.68±4.58^{ab}
	FF	nd	753.71±11.00^{c}	573.46±4.10^{de}	4159.17±40.50^{b}	1586.13±11.16^{c}	75.23±17.39^{fg}	14.18±4.46^{a}	28.93±3.03^{abc}
	NFF	17.19±8.67^{b}	352.18±17.65^{g}	359.37±33.33^{h}	3912.56±98.80^{c}	594.67±42.85^{f}	25.90±7.65^{g}	nd	21.77±5.58^{cd}
	S	254.85±7.21^{a}	420.30±32.52^{f}	434.30±8.47^{g}	794.64±19.83^{h}	499.90±4.41^{fg}	686.14±10.02^{a}	nd	23.32±6.96 ^{bcd}
L. siceraria	DL	nd	673.96±51.60^{d}	524.09±20.96^{e}	1059.82±15.89^{g}	2372.03±58.19^{b}	357.28±6.24^{d}	nd	16.30±16.20^{cde}
	FF	23.52±21.33^{b}	412.36±30.20^{f}	1158.09±103.04^{a}	4738.79±230.10^{a}	593.53±77.78^{f}	129.02±3.30^{e}	10.68±1.90^{a}	41.48±11.37^{a}
	NFF	24.47±9.48^{b}	221.45±1.96^{i}	652.10±3.63c	2740.10±61.37^{d}	342.08±11.93^{h}	25.85±1.40^{g}	11.55±6.46^{a}	11.89±1.79d^{e}
	S	31.46±18.39^{b}	391.39±25.35^{f}	546.51±42.05^{e}	1269.73±20.60^{f}	395.74±13.00^{gh}	451.80±30.02^{c}	7.20±0.35^{ab}	17.74±6.85^{cd}

Data are represented as means ± SD (n = 3). Means in the columns with no common superscript differ significantly ($p < 0.05$). DL, dried leaves; FF, fermented fruits; NFF, non-fermented fruits; S, shells; dw, dry weight. nd, non-detected. Na, sodium; Mg, magnesium; P, potassium; K, potassium; Ca, calcium; Fe, iron; Zn, zinc; Cu, cupper.

2963.95 ± 135.74 mg/100 g) from non-fermented fruits of *L. siceraria* and dried leaves of *C. lanatus* wlêwlê, respectively. The analyzed plant parts were also notable sources of magnesium, ranging from 221.45 ± 1.96 mg/100 g (non-fermented fruits of *L. siceraria*) to 872.10 ± 48.49 mg/100 g (dried leaves of *C. lanatus* wlêwlê). The phosphorus content varied from 359.37 ± 33.33 mg/100 g (non-fermented fruits of *C. lanatus* bebu) to 1158.09 ± 103.04 mg/100 g (fermented fruits of *L. siceraria*). The samples contained substantial quantities of iron that varied from 25.85 ± 1.40 mg/100 g (non-fermented fruits of *L. siceraria*) to 686.14 ± 10.02 mg/100 g (shells of *C. lanatus* bebu seeds).

DISCUSSION

The relatively lowest values of moisture obtained in this study indicated that the analyzed plant parts were in storage condition avoiding microbial spoilage (Fennema and Tannenbaum, 1996). The contents of all samples in ash suggested that they might be good sources of minerals for feedstuffs (NRC, 1994). The relatively high contents in fibres observed referred to structural carbohydrates that are composed of cellulose, hemicelluloses (pentosans, hexosans) and indigestible materials as lignin (Pottgüter, 2008). With respect to their contents in crude fibres, dried leaves, fermented and non-fermented fruits of the selected cucurbits could be used as feeds for ruminants which need fibres in their daily ration for stable and healthy digestion (Pottgüter, 2008). The dietary carbohydrate contents of seed shells of *C. lanatus* bebu and *L. siceraria* were in the range of that of cereals (80-90%), which constitute important sources of energy for poultry (Moran Jr, 1985). However, it is worth noting that the energy content of by-product feedstuffs is usually determined by the level of residual fat and percentage of fibres in the meal (Aherne and Kennelly, 1982; Schingoethe, 1991).

Polyphenols are the main dietary antioxidants and possess higher *in vitro* antioxidant capacity than vitamins and carotenoids (Gardner et al., 2000). Plant phenolics include phenolic acids, coumarins, flavonoids, stilbenes, hydrolysable and condensed tannins, lignans, and lignins (Naczk and Shahidi, 2004). Tannins present in many feedstuffs do not only affect the feed quality but can also be toxic to animals because they are often considered as anti-nutritional compounds (Lowry et al., 1996). With regards to their low contents in polyphenols, seed shells of *C. lanatus* and *L. siceraria* could be more exploited as feedstuffs for monogastrics.

Dietary requirements for protein in feedstuffs are linked to the amino acids contents. Indeed, amino acids obtained from dietary protein are used by animals to fulfill diverse functions, as primary constituents of structural and protective tissues and precursors of many important non-protein body constituents (NRC, 2001). Threonine (Thr), methionine (Met), and lysine (Lys) are essential amino acids which cannot be synthesized by animals and need to be supplied by feedstuffs (Mendonca and Jensen, 1989). The content of dried leaves of *C. lanatus* bebu in these essential amino acids was higher than those of standard protein (WHO/FAO, 1985): 2.80, 2.20, and 4.20 g/100 g protein, respectively. Therefore, the consumption of dried leaves of *C. lanatus* bebu by animals could increase their adequate growth and productivity (NRC, 1994).

The macro mineral (Ca, P, Mg, K) concentrations of the analyzed by-products were lower than the maximum tolerable levels (10-40 g/kg) for poultry (McDowell, 1992). In addition, the contents of these macro minerals could meet the requirements (200-750 mg/100g) of poly- and monogastric animals such as beef cattles, sheep and pigs (NRC, 2001). The copper (Cu) content of the shells from seeds of *C. lanatus* and *L. siceraria* was lower than the maximum tolerable level (25-30 mg/100 g) for pigs and poultry (McDowell, 1992). These plants could therefore be exploited as non-toxic feedstuffs for these monogastric animals. Indeed, copper is known to affect entero-hepatic function in small ruminants, especially sheep and goats by decreasing the ability of liver to metabolize this trace mineral (Church and Pond, 1988).

Conclusion

The data obtained in this study showed that the harvest by-products from *C. lanatus* and *L. siceraria* contained appreciable amount of ash, fibres, carbohydrate, essential amino acids and mineral elements. Consequently, the plant parts analyzed could satisfy the nutrient requirements of animals and should be used as valuable feedstuffs. However, it is necessary to consider other aspects such as the *in vivo* bioavailability of these nutrients after various feed formulations.

Conflict of interests

The authors did not declare any conflict of interest.

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