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Nutritional potential of yam chips (*Dioscorea cayenensis* and *Dioscorea rotundata* Poir) obtained using two methods of production in Togo

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Yam is one of the most staple foods in West African countries and provides an important part of the energetic for people. This study examines chemical composition of *Dioscorea cayenensis* and *Dioscorea rotundata* Poir species dried yam chips obtained using two methods of production in Togo. Three local varieties of yams (*Koukou*, *Kéki* and *Laboco*) were processed in chips and were sun dried (at 28-30°C) or oven-dried (at 50°C). Nutritive components (carbohydrates, protein fats, mineral salt, vitamin C and anti-nutritional factors) of yam chips were assessed and compared with those of fresh yam. Sugar is a major component of yam chips followed by proteins, vitamin, fats, mineral salt and anti-nutritionals factors. For the same variety of yam, the nutritional quality depends on the method of production followed and the drying methods.

Key words: Yam chips, *Dioscorea cayenensis*, *Dioscorea rotundata*, nutritional potential.

INTRODUCTION

Yam serves as an important source of carbohydrate and a major source of income in countries where they are cultivated. In 2007, 96% of the worldwide production of yam (52 million tons) was from Africa while 94% of the yam was from West Africa with Nigeria alone producing 71% (<http://www.iita.org/yam>). Yams are usually processed into dry-yam tubers/slices and flour in West African countries such as Ghana, Benin and Nigeria (Bricas et al., 1997).

Yam tubers are consumed in forms of chunks, flour, chips, fufu and slices, which are obtained from any of the processes of boiling, frying, drying, fermentation, milling, pounding, roasting and steaming (Iwuoha, 2004). The genus *Dioscorea* contains a wide range of yam species used as food. There are many varieties of yam species widespread throughout the humid tropics, the most economically important species which are grown are white yam (*Dioscorea rotundata*), yellow yam (*Dioscorea*

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cayensis), water yam (*Dioscorea alata*), Chinese yam (*Dioscorea esculenta*) aerial yam (*Dioscorea bulbifera*) and trifoliate yam (*Dioscorea dumetorum*) (Ike and Inoni, 2006). White yam (*D. rotundata*) originated from Africa and is the most widely grown and preferred yam species. The tuber is roughly cylindrical in shape; the skin is smooth and brown and has a white firm flesh. A large number of white yams exist with difference in the production and post-harvest characteristics. Yellow yam (*D. cayensis*) derives its common name from its yellow flesh, which is caused by the presence of carotenoids. It is also native to West Africa, the yellow yam has a longer period of vegetation and a shorter dormancy than white yam. In the past, yellow yam and white yam were considered as two separate species but most taxonomists now regard them as the same species, there are over 200 cultivated varieties between them. The "Kokoro" variety is important in making dried yam chips. *D. rotundata* which is referred to as dried yam contains a large amount of energy, starch, iron, the smallest amount of dietary fiber, Sn, Ca, P, Mg, Ca and Mn. The protein content is low.

Yam is a good root crop with high energy, acceptable protein and iron content but lowest in Ca and Zn. There is a high concentration of protein and minerals in the peels, which forms about 19% of the tubers. Dried yam is lower than water yam in ash content but high in soluble carbohydrate. Yam also provides protein three times more superior than the one of cassava and sweet potato. Apart from food, yams are also sources of pharmaceutical compounds like saponins and sapogenins, which are precursors of cortisone used medically in the treatment of arthritis and some allergies (Ezeocha and Ojmelukwe, 2012).

The perishability nature of yam due to its high moisture content suggests the need to process it into less perishable products such as yam chip through drying process (Karim et al., 2013). Up till today, this age-old traditional method is still being used for the processing of yam, to dry yam (yam chips) and yam flour. The quality of the chips and flour varies from processor to processor and from location to location (Ojokoh and Gabriel, 2010; Adewale et al., 2014). In Togo, this practice follows two methods: one method is according to Bassar region, the northern of part Togo and Ghana. The second method is according to Est-Mono region, Benin and Nigeria. The objective of the present study was to explore the effects of the two processing methods used in Togo on yam chips qualities, including proximate composition and anti-nutritional factors content.

MATERIALS AND METHODS

Sampling

Yam tubers of varieties "Koukou, Laboko, kéki" of *Dioscorea cayenensis* and *Dioscorea rotundata* where collected in April 2008 at Est-Mono and Bassar and dried to yam chips.

Processing of yam to dry-yam

Yam tubers were processed in to chips since May 2008 in the Microbiology Laboratory of Food stuff and Quality Control in the University of Lomé. Two methods described during the survey with farmers were adopted. Three varieties of yam were used (*Laboco*, *Kéki* and *Koukou*).

Method A

This process was used in Bassar region and in northern Togo. Yam tubers were peeled and cut into slices (0.5 to 1 cm of diameter and 5 to 10 cm of length). After washing, slices were divided into two lots. The first one was sun-dried at 28-32°C and the second was oven-dried at 50°C.

Samples process in method A (method of Bassar region):

KoBSRS: Chips of "koukou" variety processed following method of Bassar with sun drying

KoBSRE: Chips of "koukou" variety processed following method of Bassar with oven drying

KeBSRS: Chips of "kéki" variety processed following method of Bassar with sun drying

KeBSRE: Chips of "kéki" variety processed following method of Bassar with oven drying

LaBSRS : Chips of "Laboco" variety processed following method of Bassar with sun drying

LaBSRE: Chips of "Laboco" variety processed following method of Bassar with oven drying.

Method B

This process was generally used in the Est-Mono region. Yam tubers were first peeled and cut into slices (0.5 to 1 cm of diameter and 5 to 10 cm of length) and cooked at 60-70°C. Cooked slices were divided into two lots. The first was oven dried at 50°C and the second were sun-dried at the ambient air (28-32°C).

Samples process in method B (method of Est-Mono region):

KoEMNS: Chips of "koukou" variety processed following method of Est-Mono with sun drying

KoEMNE: Chips of "koukou" variety processed following method of Est-Mono with oven drying

KeEMNS: Chips of "kéki" variety processed following method of Est-Mono with sun drying

KeEMNE: Chips of "kéki" variety processed following method of Est-Mono with oven drying

LaEMNS: Chips of "Laboco" variety processed following method of Est-Mono with sun drying

LaEMNE: Chips of "Laboco" variety processed following method of Est-Mono with oven drying.

Carbohydrate content determination

Total sugar

One gram of yam flour was dissolved in 10 mL of dimethylsulfoxide (DMSO: (C₂H₆OS) 25% v/v). After 15 min of incubation in bain-marie (90-100°C), 0.1 mL of the mixture was diluted into 9.9 mL of distilled water, 0.5 mL of the last mixture were added to 0.5 mL of phenol (5%). And then, 2 mL of H₂SO₄ (75%) were added. The absorbance was read at 492 nm (Fox and Robyt, 1991).

Starch

0.1 g of yam chip flour was dissolved in 5 ml of KOH 1 N. After

homogenization, the unit was neutralized by 5 ml of HCl 1 N. The mixture thus obtained was allowed to boil for 15 min in a water-bath. After filtration, volume was adjusted to 10 mL. 0.05 mL were diluted to 5 mL with 4.85 mL of distilled water and 0.1 mL of reagent (I_2/KI) and incubated for 10 min. The absorbance of samples was carried out at 580 and 720 nm (Jarvis and Walker, 1993).

Fats content determination

Lipid content was determined using a Soxhlet apparatus and hexane reagent. 10 g of yam chip flour were weighed and were putted in a balloon. Vacuum was given before introducing 175 mL of hexane. The weight of lipids extracted was obtained by difference between the final weight P1 after evaporation of solvent and drying of the balloon and the initial weight of the empty balloon (PO).

Proteins content determination

The protein content was determined by the Kjeldahl method (AOAC, 2000) according to the following protocol:

A mixture of two catalyst tablets, 12 mL of concentrated sulfuric acid, pumice stone and 1 g of yam chips was placed in a fume hood digestion unit at 420°C for 3 h and a clear liquid was obtained. This product was diluted with 50 mL of distilled water and 75 ml of sodium hydroxyde solution 38% and then distilled in 25 mL of another mixture consisting of 4% boric acid, 25 mL (w/v) of 1-methyl red (w/v) of 1% bromocresol green (w/v) and sodium hydroxide 4% (W/V). The product obtained was titrated with 0.1 N hydrochloric acid solution until the color changes from blue to pale pink. The protein content was expressed as a percentage:

$$\text{Proteins (\%)} = \frac{1.401 \times 6.25 \times (V_e - V_b) \times T}{\text{Weight of sample in grams}}$$

T = Concentration of HCl solution; V_e = volume of hydrochloric acid used to titrate the sample (containing chips); V_b = volume of hydrochloric acid used to titrate the blank containing no chips to titrate the blank; 6.25 = the nitrogen conversion factor protein; 1.401 = constant.

Mineral content determination

Ten grams of yam chips were incinerated in a furnace (Prolabo Volca V50) at 550°C. After incineration, ash was dissolved into 100 mL of distilled water and shaken for 30 min. The solution obtained was filtered on Whatman paper No. 1. Mineral content was obtained using ionic chromatography and molecular spectrophotometry of absorption.

Ascorbic acid content determination

The ascorbic acid content of samples was determined by the volumetric method using Tillmans reagent (Sawadogo, 1993). 2.5 g of yam chip flour were dissolved in 50 mL mixture of acid solution (metaphosphoric 5%/acid acetic 10%). After 1 h of agitation, the mixture obtained was filtered. The proportioning of the vitamin in the material was carried out by using 2,6-Dichloro indol phenol (2,6-DIP) solution (0.5 mg/mL). Then, 25 mL of the filtered solution were titrated by the 2,6-DIP until the red color at the point of equivalence persists for 5 s (dryness). The quantity of vitamin was given using the reference established by the proportioning of 10 mL of pure ascorbic acid.

Determination of anti-nutritional factors (ANF)

Total oxalate

The total oxalate was determined by the method of Day and Underwood (1986). 1 g of yam chip flour was dissolved in 75 mL of sulfuric acid 15 N. The mixture was homogenized for one hour and filtered on Whatman No.1 paper. 25 mL of the filtrated solution were titrated with 0.1 N of permanganate of potassium.

Phytic acid

Phytic acid was determined according to the method of Reddy and Love (1999). This method consists of adding 4 g of flour of yam chips to 100 mL of hydrochloric acid 2% under magnetic agitation for 5 h. After filtration, 25 mL were added to 5 mL of ammonium thiocyanate 0.3%. The mixture was titrated with ferric chloride until the yellow color brown was obtained, persisting for 5 min.

Tannins

Tannins are proportioned by the method of Trease and Evans (1978). 1 mL of methanolic extract was treated with 5 mL reagent of Folin-Dennis in basic medium. The absorbance of the mixture was read at 760 nm. The content of tannins was given using a curve standard built starting from a range of concentration of gallic acid.

Saponins

Saponins was carried out according to the method of Birk et al. (1968) modified by Hudson and El Difrawi (1979). According to this method, 1 g of flour of sample was dissolved in 20 ml of the ethanol 20% (ethanol-water) under the magnetic agitation for 12 h at 55°C. The solution was filtered on Whatman No.1 and adjusted with 40 ml then 20 mL of the filtered solution was added to diethyl ether followed by a vigorous manual agitation. The aqueous phase was adjusted to pH 4.5 with a hydrochloric acid solution 0.2 N. 60 mL of the solution of N butanol were added to this phase and the unit was washed with 10 mL of NaCl 5%. The organic phase was then evaporated to have the content of saponins. The saponin was determined by the difference between the weight of the container after evaporation and the tare weight of the same container.

Statistical analysis

All analyses were carried out in triplicates and the data were subjected to analysis of Epi Info 3.5.1 for windows which was the statistical software used.

RESULTS AND DISCUSSION

Proximate composition of yam chip

The proximate compositions of yam chips manufactured by Bassar and Est-Mono processing, sun and oven dried are presented in Table 1 for carbohydrate, fat, proteins, vitamin C content, in Table 2 for anti-nutritional factors content and Table 3 for mineral content

Carbohydrate content of the chips of "Koukou" variety resulting from method of Bassar was higher to a significant degree ($P < 0.05$) than those produced with

Table 1. Proximate composition of yam chips product from “*koukou*”, “*kéki*” and “*Laboco*” (g/100 g).

Yam varieties	Samples processed	Protein (g/100)	Carbohydrate (g/100)	Fat	Vitamin C (mg/100)
“ <i>Koukou</i> ”	KoBSRS	3.47±0.2	62.61±0.05	0.11±0.02	1.19±0.39
	KoBSRE	5.71±1.23	86.57±2.72	0.14±0.02	0.71±0.07
	KoEMNS	4.05±0.07	66.40±0.07	0.19±0.01	0.84±0.21
	KoEMNE	4.34±0.45	67.79±0.04	0.1±0.09	0.73±0.07
“ <i>Kéki</i> ”	KeBSRS	4.68±0.06	44.99±0.08	0.11±0.01	0.94±0.01
	KeBSRE	4.89±0.55	55.05±0.04	0.1±0.02	0.83±0.07
	KeEMNS	3.74±0.13	37.75±0.11	0.1±0.01	0.65±0.05
	KeEMNE	4.68±0.07	43.45±0.11	0.11±0.02	0.61±0.10
“ <i>Laboco</i> ”	LaBSRS	5.58±0.16	44.21±0.24	0.09±0.05	0.05±0.00
	LaBSRE	5.43±0.23	42.40±0.06	0.13±0.02	0.2±0.02
	LaEMNS	03.6±0.28	48.85±0.11	0.13±0.01	0,3±0.01
	LaEMNE	3.92±0.52	46.62±0.09	0.13±0.06	0,1±0.03

Table 2. Anti-nutritional factors content of yam chips (mg/100).

Yam varieties	Treatment	Oxalate	Phytic	Saponin	Tannins
“ <i>Koukou</i> ”	KoBSRS	3,3±0.01	0.15±0.01	0.7±0.02	0.38±0.01
	KoBSRE	1.4±0.02	0.16±0.03	0.2±0.01	0.32±0.03
	KoEMNS	1.65±0.05	0.26±0.01	0.57±0.01	0.31±0.01
	KoEMNE	0.82±0.01	0.19±0.05	0.77±0.1	0.3±0.06
“ <i>Kéki</i> ”	KeBSRS	0.93±0.05	0.22±0.08	0.52±0.02	0.21±0.01
	KeBSRE	0.88±0.03	0.24±0.01	0.44±0.02	0.08±0.03
	KeEMNS	0.88±0.01	0.13±0.05	0.31±0.01	0.02±0.01
	KeEMNE	0.77±0.03	0.13±0.01	1.03±0.06	0.87±0.02
“ <i>Laboco</i> ”	LaBSRS	0.79±0.05	0.53±0.01	0.8±0.02	0.13±0.03
	LaBSRE	0.56±0.02	0.22±0.03	0.42±0.01	0.12±0.03
	LaEMNS	0.66±0.07	0.2±0.05	0.46±0.01	0.13±0.03
	LaEME	0.65±0.05	0.41±0.01	0.72±0.02	0.13±0.01

the method of Est-Mono, Moreover, oven drying results to less loss in carbohydrate than sun drying (Table 1).

With regards to “*keki*” variety, the chips resulting from method of Bassar associated with oven drying causes significant degree less loss in carbohydrate than those obtained from method of Est-Mono (Table 1)

For the “*Laboco*” variety, the chips resulting from method of Est-Mono associated with oven drying had less loss in carbohydrate content than the other (Table 1).

It emerges from these results that the carbohydrate content of the chips were influenced by varietal factor and transformation. In view of these results, to avoid lost of carbohydrate during the transformation of yam into chips, it is proper to choose Bassar method for *koukou* and

“*Kéki*” yam varieties and Est-Mono method for “*Laboco*” variety.

In general, it is desirable to use the oven drying because it is done quickly without allowing microorganisms to grow and alter nutrients. These results are in agreement with earlier reports of Okigbo and Nwakammah (2005) and Adewale et al. (2014). However, carbohydrate content were contrary to those obtained by Ojokoh and Gabriel (2010) and Adewale et al. (2014) with regards to “*Laboco*” and “*kéki*” varieties.

Proteins content

According to proteins content, the results indicate that:

Table 3. Mineral content of yam chips product from “*koukou*”, “*keki*” and “*Laboco*” (mg/100 g dry basis).

Yam variety	Treatment	Fe	PO ₄	Na	K	Mg	Ca	Cu	Zn
“ <i>Koukou</i> ”	KoBSRS	0.37±0.01	1859.53±4.62	105.7± 2.41	7845.2±51.03	145.82±0.97	16.69±0.11	13.53±0.02	15.48±0.00
	KoBSRE	0.34±0.1	2695.4±59.22	38.85±1.56	8840.8±41.238	142.1±2.49	13.6±0.29	4.2±1.69	13.19±2.19
	KoEMNS	0.5±0.01	2661.16±75.5	180.32±9.63	7314.37±10.54	15.88±1.42	20.09±0.18	12.21± 2.46	90.14±4.93
	KoEMNE	0.3±0.10	2024±1.16	440.29±8.78	7763.85±29.04	139.98±0.53	17.71±0.29	3.76±0.01	5.64±0.25
“ <i>Kéki</i> ”	KeBSRS	0.37±0.01	65.11±2.40	61±0.91	7679.46±27,48	315.66±0,36	23.57±0.43	6.82±3.21	28.02±7.45
	KeBSRE	0.23±0.01	36.63±0.25	26.83±3.46	6050.42±13.13	857.15±1.02	11.70±0.08	2.53±0.01	17.71±3.57
	KeEMNS	0.43±0.01	306.41±2.48	232.29±4.01	7222.56±72.96	131.09±1.45	17.34±0.07	4.81±2.26	4.81±2.26
	KeEMNE	0.32±0.01	32.98±0.33	560.05±4.01	6519.37±47.63	123.01±1.68	17,47±0.01	7.44±0.00	16.74±2.74
“ <i>Laboco</i> ”	LaBSRS	0.56±0.01	1678±0.81	56.28±1.24	6008.14±31.04	272.31±1.61	17.97±0.18	2.53±0.00	57.51±9.03
	LaBSRE	0.36±0.01	1834.71±1.22	136.71±2.11	7266.33±15.83	246.97±5.30	17.34±0.07	4.26±0.00	30.9±7.28
	LaEMNS	0.58±0.,03	1494.67±3.19	67.67±0.06	5488.95±35.21	260.75±13.68	25.1±1.13	6.01±2.84	24.06±2.25
	LaEMNE	0.47±0.01	1415.33±2.56	107.06±0.90	6683.2±39.22	427.16±2.67	30.55±0.58	9.3±2.25	22.9±3.23

1. Regarding “*koukou*” variety, the method of Bassar combined with oven drying would preserve the content of proteins better with significant degree ($P < 0.05$) than the method of Est-Mono.

2. For “*kéki*” variety, method of Bassar combined with oven drying caused no significant degree less loss of proteins. With “*kéki*” variety, no influence of method production and drying method on the protein content was seen.

3. “*Laboco*” variety gave the same observations like “*koukou*” variety.

The protein contents obtained were contrary to those obtained by Oyeyiola et al. (2014), Adewale et al. (2014) and Ojokoh and Gabriel (2010) who obtained lower protein content of yam chips.

Fats content

The results reveal that the content of fat is very low and which is about 0.1, varietal influence and transformation process are not significant (Table

1). This content were in agreement with earlier reports (Oyeyiola et al., 2014) but were contrary to those reported by Adewale et al. (2014) and Ojokoh and Gabriel (2010) who obtained higher content of fat.

Vitamin C content

The results indicated that vitamin C content varies from 0.71 to 1.19 mg for “*koukou*” chips, 0.6 to 0.94 mg for chips of “*kéki*” and 0.05 to 0.3 mg for “*Laboco*” chips. Process and variety did not influence significantly vitamin C content (Table 1). Vitamin C content was contrary to those obtained by Gbolagade et al. (2011) who reported higher content of ascorbic acid (4.44 -6.46 mg/100 g).

Anti-nutritionals factors content of yam chips

The edible, matured yam does not contain any anti-nutritional factors however, bitter components

tends to accumulate in immature tuber tissues of *D. rotundata* and *D. cayenensis*. They may be attributed to polyphenols or tannin-like compounds. Some workers (Asuzu and Undie, 1986; Okeola and Machuka, 2001; Ajibade et al., 2005) have identified the presence of some anti-nutritional factors (ANF) such as alkaloids, flavonoids, saponins, lectin, trypsin inhibitors, phytate and oxalate in the African yam. List of the anti-nutritional factors in the African yam bean includes trypsin inhibitor, haemagglutinating, tannic acid (tannins), phytic acid, oxalate (Apata and Ologhobo, 1997). In addition to the above list of ANF are α -galactosides (stachyose) and lectin (Oboh et al., 1998).

For “*Koukou*” variety, the oxalates deteriorate more with method A with sun drying, whereas the content of phytate does not vary to a significant degree according to the yam chips methods of production used ($P > 0.05$). The method of Est-Mono (MN) associated with oven drying and those of Bassar (BSR) with sun drying caused more loss of total phenols. The content of tannins and

saponins varies less with the method of Est-Mono associated with sun drying.

As compared to "keki" variety, the oxalates content decreases with method of Est-Mono associated with sun and oven drying (50°C) and the drying oven with 50°C. The phytate content remains constant. Total phenols and saponins content deteriorated by the bleaching with oven drying. The content of tannins varies less with the method of Bassar (BSR) associated with sun and oven drying, whereas the method of Est-Mono (EMN) with sun and oven drying caused more deterioration in yam chips

For "Laboco" variety, the phytate and oxalate content of yam chips decreases less with the method of Bassar (BSR) associated with sun drying, whereas it decreases much more with method of Est-Mono (EMN) with sun and oven drying (50°C). The tannins and saponins contents remain constant with the other experimental conditions. However, these variations observed between the various treatments are not significant ($P > 0.05$).

The anti-nutritional factors are substances of reserves of plants which complex some nutrients like rock salt, proteins and reduce their bioavailability during digestion. It is the case of oxalates, the phytate, saponins, tannins and total phenols, etc. These results of content of anti-nutritional factors were lower than those reported by other authors on the yam and these studies relate to only the fresh tubers. Thus, Jau-Tien et al. (2009) found saponin values in the yam from 247 to 619 µg/g. FAO (1991) found 637 mg/100 g for the phytate.

Rock salt content of yam chips

The samples of yam chips contain a broad rock salt range the cations (Mg, Na, K and Ca), anions (Cl, SO₄, PO₄, Br, NO₂ and NO₃) and oligo elements (Zn, Cu and Fe). Only the principal ones are illustrated here.

For "Koukou" variety, the most representative oligo elements were zinc with contents between 5.64 and more than 90 mg per 100 g of dry matter, followed by copper with 3.76 to 13.53 mg. The content of iron is very weak and varies from 0.3 to 0.5 mg per 100 g.

Among the anions, phosphorus is most significant with contents from 1859 to 2695 mg per 100 g whereas among the cations, potassium is most significant with values ranging from 7314 to 8840 mg per 100g. According to "Kéki" variety, potassium and phosphorus are the principal biogenic salts with contents respectively from 6050 to 7679 mg and 1625 to 2634 mg/100 g. Oligo significant elements were Zn with content varying from 8 to 28 mg/100 g followed by copper whose values were from 2.53 to 7.44 mg/100 g. Concerning "Laboco" variety, potassium and phosphorus are the principal biogenic salts with contents respectively from 5488 to 7266 mg and 1415 to 1834 mg/100 g. The Mg, Na and Ca were slightly represented in all the samples of the variety. Oligo significant elements were Zn whose content

varies from 22.9 to 5.51 mg /100 g followed by the copper whose values went from 2.53 to 9.3 mg/100g. Iron is the oligo element most slightly represented in the studied yam chips.

This study revealed that yam chips contain majorly potassium and phosphorus. FAO (1970) showed mineral salt dominating in yam is potassium thus, yam could cover a substantial part of the requirements of manganese and phosphorus for the adults. Our results were contrary to those obtained by Agbor-Egbé and Streche (1995) which found 65-125 mg/100 g of phosphorus; 8-36 mg for calcium; 590-1740 mg for potassium; 19-72 mg for magnesium.

Conclusion

The proximate compositions of yam chips for each yam variety, for drying and processing methods showed that these products have an important nutritional potential. Outside carbohydrates, protein, fat, vitamin C, minerals, the chips also contains anti-nutritional factors. There are no significant effects of processing ($P > 0.05$) on lipid, vitamin C, mineral and anti-nutritional factors. In contrast, yam variety, drying and processing methods have significant effects on carbohydrates and proteins content. This can be exploited to provide food for diabetics, as an ideal food source of carbohydrates without affecting their disease.

Conflict of interests

The authors did not declare any conflict of interest.

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