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Impact of different drying methods on nutritional quality of *Garcinia cowa* and *Garcinia pedunculata* fruits

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Abstract

Aim: The present study was undertaken to establish a suitable drying process for *Garcinia cowa* and *Garcinia pedunculata* fruits for maximum retention of their nutritional qualities.

Methodology: Slices of three different thickness with 0.3, 0.6, 0.9 cm of *G. cowa* and *G. pedunculata* fruits were dried by sun drying, solar drying and by cabinet drying at three different temperatures (50°C, 70°C and 90°C).

Results: The mean crude fat and ash content were higher in *G. cowa* than *G. pedunculata* while later was found rich in crude protein and Fe contents. Total phenol content ranged between 881.31-888.65 and 719.00-736.74 mg gallic acid equivalent 100 g⁻¹, total flavonoid content between 89.21-90.06 and 51.00-52.54 mg quercetin equivalent 100 g⁻¹ and mean HCA contents ranged between 3.13-3.92% and 1.84-1.99% for *G. cowa* and *G. pedunculata*, respectively. The methanolic extracts exhibited significant antioxidant activity. With lower IC₅₀ values, *G. cowa* had higher antioxidant activity than *G. pedunculata*.

Interpretation: Oven drying at 50°C and 0.9 cm slice thickness for drying resulted in better retention of total phenolic and flavonoid contents with better antioxidant activities.

Five different drying methods each with three different slice thickness of *Garcinia cowa* and *Garcinia pedunculata* fruits were used for nutritional evaluation

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| I. Drying methods | 1. Cabinet drying at 50°C
2. Cabinet drying at 70°C
3. Cabinet drying at 90°C
4. Sun drying
4. Solar drying |
| II. Slice thickness (0.3, 0.6, 0.9 cm) | 1. 0.3 cm
2. 0.6 cm
3. 0.9 cm |



Different nutritional parameters like crude protein, crude fat, ash, iron, calcium, hydroxycitric acid, phenol, flavonoids, antioxidant activity etc. were assessed

The results based on ANOVA, showed significant differences in respect of thickness of slices and drying methods for all the parameters studied. Oven drying at 50°C and 0.9 cm slice thickness for drying resulted in better retention of total phenolic and flavonoid contents with better antioxidant activities.

Key words: Antioxidant, Borthekera, Drying method, *Garcinia*, Kujithekera

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Introduction

The genus *Garcinia* (Family: Clusiaceae) is one of the underutilized fruit crops with potential therapeutic properties, consisting over 200 species distributed in the tropics of the world. In India, there exist about 35 species of *Garcinia* which are endemic with substantial medicinal properties. *Garcinia pedunculata*, *G. kydia*, *G. cowa* and *G. lancifolia* are some important species of North Eastern parts of India. Many species of *Garcinia* have fruits with edible arils and have tremendous potential as spice and medicinal plants. The dried fruit rind with sweet acid taste is traditionally used for culinary purposes as a condiment and flavouring agent. In North-Eastern India, the sun-dried slices of *Garcinia* fruits are used for edible and curative purposes (Gogoi et al., 2016). *Garcinia cambogia*, *G. indica* and *G. cowa* are some of the cultivated species in some parts of India.

Garcinia is a rich source of secondary metabolites with bioactive phytochemicals. Many of the isolated compounds possess anticancer, anti-inflammatory, antibacterial, antiviral, antifungal, anti-HIV, antidepressant and antioxidant properties. Garcinol present in *Garcinia* is found to elicit anti-cancer properties by regulating different cellular processes (Aggarwal et al., 2020). Nhan et al. (2020) isolated several xanthone derivatives from *G. delpayana* that showed potential anti-inflammatory properties. Traditional use of *G. cambogia* fruit pericarp extracts in multiple traditional medicinal system to treat bacterial diseases and cancer was validated by Hart and Cock (2016). The juice and ethanolic extract of *G. mangostana* leaves have possible antifungal and antibacterial activity (Diniatik et al., 2019) whereas the fruit rind of *G. indica* has significant antidepressant and anxiolytic effect (Dhamija et al., 2017). The main component of fruit rind is garcinol, isogarcinol and camboginol. Garcinol and isogarcinol in various *Garcinia* species are reported to have activity against cancer, pathogenic bacteria, parasite infections and various inflammatory diseases (Schobert and Biersack, 2019). The antioxidant activity of garcinol has been identified as the basis for various bioactivities in *Garcinia* (Liyanagamage et al., 2020). The major organic acid in the fruit rind of *Garcinia* is hydroxycitric acid (HCA), a proven natural antiobese agent (Onakpoya et al., 2011). Tomar et al. (2019) reported the anti-obesity effects of HCA with the help of clinical data and metabolic model analysis. They found that HCA treatment reduced body weight gain and fat accumulation in obese subjects. Hydroxycitric acid has been proved to combat obesity by promoting reduced glucose absorption, decreased appetite and improved lipid profile (Ferreira et al., 2020).

In Assam, *Garcinia* is commonly known as “thekera” has rich traditional uses. Young leaves are eaten by some tribes, the latex of *G. cowa* is used in Thai folk medicines as an antifever agent, also used for menstrual problems, dysentery and fever in traditional system of medicine. Two of the *Garcinia* species of this region, *G. cowa* Roxb.,” and *G. pedunculata* Roxb., locally known as “kujithekera and borthekera” are popular for their acidic fruits and dried fruit slices are preserved for preparing different dishes

and to treat dysentery. Folk people use cold water infusion of dry pericarp as antidiarrhoeic, antidysentric, in dyspepsia and flatulence (Kagyung et al., 2010). The sun-dried slices of *G. pedunculata* are also used in culinary purposes. The fruits of both these species are rich in hydroxycitric acid. Despite health benefits of *Garcinia*, the fruits of *G. cowa* and *G. pedunculata* remain underutilized. Fruits are highly perishable and needs preservation for use during off season. Drying helps their storage at ambient temperature. Open sun drying (OSD) is the most common method of drying practised for *Garcinia* fruits in Assam. However, the method is affected by different factors like wind speed, relative humidity, product thickness, effective sun-shine hours etc. This is a slow drying process with chances of mold growth deteriorating the quality of dried products. Two other drying methods commonly practised include solar drying and oven drying. However, drying might cause degradation of nutritional substances with undesirable colour changes of the products. The present study was, therefore, designed to establish a suitable drying method for *Garcinia* species and to assess its effects on the nutritional quality of dried products.

Materials and Methods

About 15 kg of fresh, mature fruits of *G. cowa* and *G. pedunculata*, just before ripening were collected from the Experimental Farm, Department of Horticulture, Assam Agriculture University, Jorhat. Fruits were washed thoroughly under running tap water and wiped dry. The unpeeled fruits were cut into half, seeds removed and then sliced to the required thickness, 0.3, 0.6 and 0.9 cm using mechanical slicer. Slices of two fruit species were spread over aluminium tray separately for sun drying. Oven drying was performed in the electrical tray dryer at three different temperatures set at 50°C, 70°C and 90°C. Solar drying was carried out by keeping the slices at solar cabinet dryer designed by Rajasthan Agricultural University, Udaipur, India. The weight of dried slices was determined at intervals of 2 hours till constant or near constant weight were obtained. After complete dryness, the samples were allowed to cool, slices were ground to form a powder, sieved (20 mesh), packed in a zip lock polyethylene bag and stored at room temperature for further analysis.

Moisture content, titratable acidity, total soluble solids, pH, crude fat, crude protein, ash content were determined as per the procedure of AOAC (2000). The moisture content of fruits and slices of different thickness was determined gravimetrically by subtracting the weight of dried sample from the weight of fresh sample. The titratable acidity of flesh juice was estimated by the volumetric method using phenolphthalein as an indicator and expressed as grams of citric acid per 100 ml. Total soluble solid were read using Abbe's hand refractometer (0-32°C) having automatic temperature correction facility and was expressed in °Brix. The pH of flesh juice was determined by a glass electrode pH meter. Crude fat was determined by automatic fat extraction unit (SOCS PLUS, Pelican, India) using petroleum ether as an extracting solvent and was expressed as a percentage of crude

fat on moisture free basis. Crude protein content was determined by micro Kjeldahl method using automatic digestion unit (KEL-PLUS, model KES04L, Pelican, India), followed by distillation and titration and the nitrogen content was multiplied by a factor (6.25) to calculate protein content. Ash content was determined using 5 g moisture free powdered sample in a silica crucible, charred in low Bunsen flame and finally ignited at 600°C for 6 hrs in the muffle furnace and ash was dissolved in HCl (1:1) on a water bath at 100°C and the solution was evaporated to dryness, volume made up to 100 ml with glass distilled water. Iron content was determined following the method described of Wong (1928) using UV-Visible spectrophotometer (Chemito, UV -2100 model).

The concentration of iron present in the sample was calculated from the standard curve (taking iron as standard) and expressed as mg Fe 100 g⁻¹ sample. Calcium was determined using flame photometer as per the method described by AOAC (1984). A stock solution of calcium (200 ppm) was prepared and different concentrations of the solution were placed under Nebuliser and the intensity of emitted lights was measured. The concentration of sample solution was calculated from the standard curve prepared using calcium. HCA was determined by the spectrophotometric method as described by Benny et al. (1999). A standard was prepared by using ethylenediamine salt of HCA (98% ED-HCA). The absorbance of slight orange colour was read in UV-visible spectrophotometer (Varian Cary 50 Scan) at 467 nm. The amount of HCA in the sample was calculated from the standard graph. Total phenol was assayed following the method of Singleton and Rossi (1965) as described by Malik and Singh (1980) using Folin-Ciocalteu reagent in alkaline medium to produce a blue-coloured complex (molybdenum blue) and the absorbance was read on UV-visible spectrophotometer (Varian Cary 50 Scan) at 650 nm expressing total phenol as mg catechol 100 g⁻¹ sample.

Total flavonoids content were determined by spectrophotometric assay based on aluminium complex formation initially proposed by Christ and Müller (1960) and as described by Aiyegrero and Okoh (2010) and the absorbance was

read at 415 nm on a UV-visible spectrophotometer (Varian Cary 50 Scan). Quercetin was used as standard and the result was expressed as mg of quercetin equivalents 100 g⁻¹ d.wt. Antioxidant activity was measured by the method of Blois (1958) and as described by Vani et al. (1997) using DPPH. The concentration of the sample required to decrease the DPPH concentration by 50% was obtained by interpolation from the linear regression curve and denoted IC₅₀ value (µg) using ascorbic acid as a reference compound. The reducing power of *Garcinia* samples was determined by the method of Oyaizu (1986). The absorbance was measured at 700 nm and ascorbic acid was used as standard. Increased absorbance of the reaction mixture indicates an increase in reducing power and reducing power was expressed as L-ascorbic acid equivalent per 100 g⁻¹ dry sample. The results obtained were subjected to analyses of variance in factorial completely randomized design with three replications to interpret the results. All drying operations and chemical analyses for fresh fruits and slices of three different thicknesses were carried out in triplicate.

Results and Discussion

The results of the study based on ANOVA (Table 1, 2) showed significant differences on the nutrient and phyto-chemical composition of two *Garcinia* species-*G. cowa* and *G. pedunculata* with respect to thickness of fruit slices and drying methods used in the study. *Garcinia cowa* was found superior over *G. pedunculata* in different parameters studied. *G. cowa* fruits were rich in different nutritive constituents such as crude fat, crude protein, ash, calcium, iron etc., than that of *G. pedunculata* (Table 3). Higher phenolics and flavonoid contents in *Carissa edulis* Vahl dried fruits was reported to have higher antioxidant activity with better IC₅₀ values and thus can act as a good free radical scavenger (Fowsiya and Madhumitha, 2017). Higher proportion of phenolic compounds in *G. cowa* with better IC₅₀ value and reducing power might be useful as a potential preventive intervention for free radicals mediated diseases. The moisture content of whole fruits of *G. cowa* and *G. pedunculata* were found

Table 1: Analysis of variance of thickness, drying techniques and interaction for *G. cowa*

Source of Variation	d.f	Means Squares								
		Crude fat (%)	Crude protein (%)	Ash (%)	Fe	Ca	HCA (%)	Total phenol	Total flavonoid	IC ₅₀ (µg ml ⁻¹)
		(mg 100g ⁻¹)					(mg 100g ⁻¹)			
Thickness	2	0.001	0.239*	0.006*	1.374*	1.436*	2.545*	254.813	2.767*	5.184*
Drying method	4	0.023*	1.989*	0.019*	7.490*	5.623*	1.155*	8,321.777*	263.240*	4.591*
Interaction of thickness and drying method	8	0.001	0.074*	0.000	0.074*	0.166*	0.204	285.956	0.615*	1.744*
Error	30	0.001	0.000	0.000	0.000	0.000	0.202	185.612	0.265	0.004
Total	44									

*Significant at 5% probability level

Table 1: Analysis of variance of thickness, drying techniques and interaction for *G. pedunculata*

Source of variation	Degree of freedom	Means Squares								
		Crude fat (%)	Crude protein (%)	Ash (%)	Fe (mg 100g ⁻¹)	Ca (mg 100g ⁻¹)	HCA (%)	Total phenol (mg 100g ⁻¹)	Total flavonoid (mg 100g ⁻¹)	IC ₅₀ (µg ml ⁻¹)
Thickness	2	0.006*	0.119 *	0.002*	3.618 *	3.282*	0.096	1,248.306*	11.479*	17.916*
Drying method	4	0.006*	0.870*	0.057*	25.517*	2.844*	0.590*	24,202.928*	288.231*	2.675*
Interaction of thickness and drying method	8	0.004*	0.056*	0.001*	2.119*	0.330*	0.108	1,699.436*	11.372*	10.666*
Error	30	0.000	0.019	0.001	0.000	0.000	0.073	52.791	0.082	0.708
Total	44									

*Significant at 5 % probability level

Table 3: Biochemical characteristics of *Garcinia cowa* and *Garcinia pedunculata* fruits

Composition	<i>G. cowa</i>	<i>G. pedunculata</i>
Moisture (%)	88.17±0.03	88.47±0.05
Total titratable acidity (%)	1.65±0.30	2.13±0.28
Total soluble solid (°Brix)	9.06±0.90	6.06±0.25
Juice pH	1.78±0.03	1.80±0.05
Crude fat (%)	1.35±0.02	1.25±0.02
Crude protein (%)	3.95±0.14	4.97±0.19
Ash content (%)	2.49±0.25	1.86±0.03
Iron content (mg/100 g)	11.9±0.01	17.51±0.02
Calcium content (mg/100 g)	15.17±0.12	14.66±0.01
HCA content (%)	4.29±0.03	2.57±0.01
Total phenol content (mg/100 g)	922.50±0.02	819.38±0.04
Total flavonoid content (mg/100 g)	99.31±0.02	59.88±0.03

*Values represented in the table are mean ± SD of three replication

to be 88.17 and 88.47% (wet basis). Drying to a constant moisture level was found to be dependent on the thickness of material and drying method used. Thinner the slices, shorter were the time required for drying in all the drying methods and higher temperature, lower was the time required to achieve a constant weight. In the present study, with slice thicknesses of 3, 6 and 9 mm and oven temperature of 50°C, the time required for drying was found to be 4.5, 7.5 and 8.5 hrs for *G. cowa* and 5, 7 and 8.5 hrs for *G. pedunculata*, respectively. With rise in oven temperature, time requirement was lowered. Solar drying was found more effective over sun drying in reducing the moisture content to a constant level in *Garcinia* slices. For *G. cowa*, sun drying was completed in 7-11 days (40.5-61 BSSH) depending on slice thickness where as 6-8 days (35.8-46.4 BSSH) were required to reduce the moisture content to a constant level by solar drying. For *G. pedunculata*, sun drying required 8-10 days (39.5-48.1 BSSH), while solar dryer drying was completed in 6-8 days (28.7-39.5 BSSH). The requirement of lesser time for solar drying might be due to higher temperature available within the dryer (Das and Sarma, 2001). During study, maximum 18°C

higher temperature than the ambient was recorded in the solar dryer. All the drying methods used in the study were found suitable for the production of dried *Garcinia* for safe storage.

The methods will produce semi-moist products, however, due to high acidic content of the fruits, they can be easily preserved. Crude fat content was higher in *G. cowa* (1.35%), but *G. pedunculata* was found as a better source of crude protein with 4.97% than *G. cowa* with 3.95%. In dried slices, crude fat varied between 1.12-1.28% in *G. cowa* and 1.12- 1.21% in *G. pedunculata*. However, crude fat contents in different *Garcinia* species were reported to be lower than these values (Nurminah et al., 2019). Drying resulted in the loss of crude fat content in *Garcinia*, with lowest average fat content in oven dried samples dried at 90°C. This might be due to volatilization of low molecular weight fatty materials. Drying methods had a significant effect on the crude protein content in *Garcinia*, higher temperature was found to lower the crude protein content.

The average crude protein content in dried *G. cowa* was 2.83-3.08% and 4.47-4.65% in *G. pedunculata*. The effect of slice

thickness on crude protein content was also found significant. Higher the slice thickness, greater was the crude protein content in dried *Garcinia*. Slice thicknesses and drying temperatures showed significant effects on the ash content in *Garcinia*. The average ash content in *G. cowa* was 2.13-2.18% and in *G. pedunculata*, it ranged between 1.60-1.62%. Increased slice thickness and higher temperature resulted in higher ash content. Highest ash content was found in samples oven dried at 90°C and the slices of 0.9 cm thickness. On dry weight basis, *G. pedunculata* had more iron content than *G. cowa*. Oven dried (50°C) samples showed the highest iron content.

The average calcium content in *G. cowa* was 13.32-13.91 mg 100 g⁻¹ and 12.92-13.85 mg 100 g⁻¹ in *G. pedunculata*, respectively. With the increase in slice thickness, iron and calcium contents were found increasing significantly in both *G. cowa* and *G. pedunculata*. Sun-dried thicker slices were found to retain maximum calcium while solar drying resulted in least. Higher temperature may cause some leaching and loss of minerals leading to some error in estimation. Hydroxycitric acid (1,2-dihydroxypropane-1,2,3-tricarboxylic acid) is the principal organic acid present in the fruit rind of *Garcinia* species. *Garcinia cowa* is a better source of HCA than *G. pedunculata* with 4.29% and 2.57% HCA in the two species respectively on a dry weight basis. There were significant effects of slice thickness, drying methods and their interactions on HCA content in *Garcinia* species. Drying methods caused a reduction in HCA content. The maximum HCA (4.06%) was observed in the slices dried at 70°C in case of *G. cowa*, while in *G. pedunculata*, the maximum HCA (2.25%) was found in oven dried slices at 90°C. Bainto *et al.* (2018) reported that samples dried at 60°C yielded the highest concentration of HCA (4.46 %), followed by 70°C (4.22%) and 50°C (4.03%) in *G. binucao* fruit pulp.

Garcinia cowa and *G. pedunculata* had 922.50 and 819.38 mg catechol equivalent of phenol 100 g⁻¹ which was reduced during drying. Decrease in TPC during drying could probably be attributed to binding of polyphenols with other compounds (proteins) or alterations in the chemical structure of polyphenols which cannot be extracted or determined by available methods (Qu *et al.*, 2010). In dried material, highest average total phenol content was found in oven dried materials dried at 90°C and the lowest was recorded for the sun-dried materials. The high retention of phenolic compounds in *Garcinia* slices dried at 90°C could be due to the availability of precursors for non-enzymatic inter-conversion between phenolic molecules (Vega-Galvez *et al.*, 2009). Moreover, faster drying rate at 90°C might decrease the degradation of TPC through the oxidation process. The higher total phenolics might also possibly due to the liberation of phenolic compounds from the matrix during the drying process. Lower drying temperatures probably did not inactivate the oxidative enzymes completely, which might have in turn, resulted in oxidation of the phenolic substances and resulted in a relatively lower phenolic content.

Drying also caused a decrease in the total flavonoid content in *Garcinia* under study. Total flavonoid content in *G. cowa* was decreased from 99.31 to 89.21-90.06 mg QE/100 g and from 59.88 to 51.00-52.54 mg QE/100 g in *G. pedunculata*. The loss of flavonoids during drying may be due to the process conditions, in particular, the temperature and duration (Michalczyk *et al.*, 2009; Schieber *et al.*, 2001). Effect of slice thickness, drying methods and their interaction were significant for flavonoid content. Mean total flavonoid content was highest in the oven dried materials dried at 50°C (98.98 and 57.86 mg QE/100 g) and the lowest was recorded for the sundried materials (85.15 and 44.02 mg QE/100 g) for *G. cowa* and *G. pedunculata* respectively. Slices with 0.6 cm thickness showed the highest flavonoid contents. Both total phenol and flavonoids can act as free radical scavengers. The free radical scavenging activities of *Garcinia* species were co-related to both phenolic and flavonoid contents (Gogoi *et al.*, 2015). DPPH system is one of the most widely used tools in determining free radical scavenging activities of antioxidants. Free radical scavenging activities were found higher in *G. cowa* than in *G. pedunculata* because of higher total phenol and total flavonoid contents in *G. cowa*. There was an increased activity with the increased concentration of the extract. The highest activity was shown by 50°C oven dried sample at 100 µg concentration for both *G. cowa* (84.9±0.03 % inhibition) and *G. pedunculata* (77.6±0.04 % inhibition). Standard ascorbic acid showed higher (93.32±0.03% inhibition) activities at the same concentration.

There were significant differences in the IC₅₀ values for the slices of different thicknesses dried through different methods. Lowest IC₅₀ values were found for the samples dried at 50°C and the highest with sun-dried samples. Sun-dried samples of both *G. cowa* and *G. pedunculata* had the lowest total phenol and flavonoid contents and hence the highest IC₅₀ value. Sun-drying was reported inferior to retain quality of dried *Garcinia cambogia* by Lim *et al.* (2020). Higher antioxidant activity in the 50°C oven dried samples might be due to the combined action of phenols, flavonoids and other compounds.

Garcinia cowa extracts also showed higher ferric reducing antioxidant power than *Garcinia pedunculata*. *Garcinia cowa* was found to be a better source of nutrients and phytochemicals than *G. pedunculata*. Drying lowered the nutrient and phytochemical contents of *Garcinia* species. Oven drying was found better over the sun and solar drying. The thickness of slices was also found to have significant effects on the nutritional quality. Comparatively, oven drying at 50°C and 0.9 cm material thickness for drying resulted in better retention of total phenolic and flavonoid contents with better antioxidant activities.

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Add-on Information

Authors' contribution: I. Sagolsem: Resources, Methodology, Investigation; S. Rathi: Data analysis, writing original draft; S. Baishya: Data analysis, writing final draft.

Research content: The research content of manuscript is original and has not been published elsewhere.

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