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Original Article

Comparison of antioxidant properties of dehydrated fruits and vegetables with different drying techniques

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Abstract
Present study was carried out to evaluate the effect of various dehydration techniques such as sun drying, solar drying, drying after freezing (Freeze for one hour followed by mechanical drying), vacuum drying and drying using lab scale air oven on retention of antioxidants in different fruit and vegetable powders prepared from fruits such as Bael (*Aegle marmelos*), Palmyra (*Borassus flabellifer*) and vegetables; Pumpkin (*Cucurbita maxima*) and Hibiscus (*Hibiscus rosa-sinensis*). The major antioxidants present such as total phenolic content, β – carotene and total anthocyanin content were determined (n=3) in fruits and vegetables which were dehydrated by different drying methods. The retention of antioxidant activity was evaluated by conducting the DPPH scavenging activity using methanol as a solvent. The results were analyzed by complete randomized design using ANOVA (SAS statistical package) and mean separation was done by using Least Significant Difference (LSD) at $\alpha = 0.05$. Higher retention of β - Carotene and total phenolic content was recorded in vacuum dried samples significantly ($\alpha < 0.05$). Sun drying and solar drying were significantly affected on reduction of the retention of total phenols. Hibiscus powder contained higher level of anthocyanin; dehydrated beal, palmyra and pumpkin retained higher concentration of β -Carotene and total phenolic content by vacuum drying.

INTRODUCTION

Fruits and vegetables are very good source of essential nutrients such as vitamins, minerals, fiber and major antioxidants. It also beneficial to protect from age related diseases, cancers and heart diseases. Antioxidants are chemical compounds that can bind with free oxygen radicals and prevent damaging the healthy cells, whereas pro-antioxidant act indirectly either by modulation of direct agents or by regulation of the biosynthesis of antioxidant proteins. In recent years increasing attention has been paid to the role of diet in human health and among antioxidants, vitamin C has many biological activities on human body reducing level of C-reactive protein, a marker of inflammation and possibility a predictor of heart diseases [1]. Polyphenols and carotenoids are plant secondary metabolites which are well recognized as natural antioxidants linked to the reduction of the development and progression of life-style related diseases. Plant carotenoids are the primary dietary source of provitamins worldwide, with carotene as the most well-known provitamin A carotenoid or retinol that can be converted to retinol vitamin A. The best-known carotenoid is carotene. Vitamin A is a group of compounds that play an important role in vision, bone growth, reproduction, cell division, and cell differentiation [2]. Vitamin A helps regulate the immune system, which helps prevent or fight off infections by making white blood cells that destroy harmful bacteria and viruses [3]. Vitamin A is obtained in two ways namely as vitamin A from animal sources such as liver, fish oils, egg yolks, and dairy products and the other as carotene from many fruits and vegetables which the body converts to retinol in the small intestine. It also helps in growth and development. Hence preservation of these fruits and vegetables becomes necessary.

Storage of fresh vegetables is the best way to maintain its nutritional value, but most storage techniques require low temperatures, which is difficult to maintain throughout the distribution chain. Drying is the suitable alternative for postharvest management especially in tropical countries such as Sri Lanka. In sufficient low temperature distribution system and handling facilities in Sri Lanka leads product contamination and deterioration. Therefore development of alternate drying technologies and methods are depends on various factors such as type of product, availability of drier, cost of dehydration and final quality of the product [4]. Therefore the objective of this study was to determine the influence of different drying methods to preserve antioxidants properties of the selected fruits and vegetables.

MATERIALS AND METHODS

Sample preparation

The fruits such as, Bael (*Aegle marmelos*), Palmyra (*Borassus flabellifer*) and the vegetables such as Pumpkin *(Cucurbita maxima)*, *Hibiscus (Hibiscus rosa-sinensis)* were used to prepare powder by different dehydration techniques like sun drying, solar drying, drying after freezing (Freeze for one hour followed by drying using lab scale air oven at 55°C), vacuum drying at 50 °C and drying using lab scale air oven at 55°C. The diseased and damaged fruits were sorted out where as remaining were washed and pulp was taken. Fruit powders were prepared by drying followed by grinding it in a mixer grinder and shifted to get fine partials (150 µm).

Determination of antioxidant properties of fresh and dehydrated fruits and vegetables

β -Carotene: β -Carotene content was determined using High Performance Liquid Chromatography (C-R6A, Shimadzu, Japan). Five grams of fruit sample was saponified with 20 ml of 95% ethanol and 5ml of 100% KOH and refluxed for 30 min at 85°C. The mixture was extracted with hexane until the sample become colorless. The extracted sample was then filtered through a 0.45µm. nylon membrane filter and analyzed using revised-phase high performance liquid chromatography .The test solution was injected under isocratic conditions into the µBondpack C_{18} column (300nm x 3.9mm, 125A, 10µm) with a ternary mixture of acetonitrile-methanol-ethyl acetate (88:10:2 v/v) as mobile phase with the flow rate of 1.0 ml/minute. Detection was performed at 436nm. The results expressed as µg/100g in dry weight [5].

Standard preparation of β -Carotene: Standard of β - Carotene solutions were prepared by taking 10mg in 100 ml n-Hexane. The standard solutions were prepared as 20, 40, 60, 80ppm dilutions of 5ml of each n-Hexane solutions.

Total phenoloic content (TPC): Total phenolic content (TPC) of dehydrated food samples were measured and the results were expresses as mg gallic acid equivalents per g of sample as gallic acid as the standard [6].

Anthocyanin content: The anthocyanin pigments in dried of powder in tampala and hibiscus flower were extracted with a solvent mixture of acidic ethyl alcohol and the intensity of colour was measured through 535nm wavelength in a UV- spectrophotometer against the blank. The amount of anthocyanin present in the sample was expressed as mg/100g [7].

Determination of the antioxidant activity:

Solvent extraction process

Extraction was performed according to which was modified [8].1 g of powdered samples were dissolved in 100 ml of methanol and kept at room temperature for 48 h. The extracts were filtered through a Whatmann filter paper and concentrated using a rotary evaporator at 40 °C.

Antioxidant screening

The DPPH assay (1, 1-diphenyl-2-picryl hydrazyl)/ free radical scavenging assay was followed [9]. The solvent extracts of the sample were taken in the following concentration range i. e., 200, 400, 600, 800, 1000 µL in each test tube and the volume was made up to 1 mL with the solvent and 3 mL of 0.1 mM DPPH is added to all the tubes. The mixture was shaken well and incubated at room temperature for 30 minutes and absorbance was measured at 517 nm using a UV- spectrophotometer. All the experiments were performed in triplicate and the mean was taken. Scavenging activity was calculated from control sample OD using the following equation

Radical Scavenging Activity % = {(Ac –At) / Ac} x 100

Where, Ac-Absorbance of control;

At- Absorbance of test solution /sample

Statistical analysis

Data obtained were in triplicate (*n=3*) and the results were assessed by completely randomized design using ANOVA by SAS statistical package. Mean separation was done by using Least Significant Difference (LSD) at α= 0.05.

RESULS AND DISCUSSION

Determination of antioxidant composition of dehydrated fruit powders:

β -Carotene and total phenolic content of dehydrated beal and palmyra fruit powder with different drying methods are given in table 1 and 2 respectively.

Table 1 β -Carotene content (µg/100g) of dehydrated beal and palmyra

Fruit	β -Carotene (µg/100g) Solar drying	Oven drying x̄±SD	Freeze prior to drying x̄±SD	Sun drying x̄±SD	Vacuum drying x̄±SD
Beal	1964.74±0.64^{e}	1134.88±0.02^{d}	1291.08±0.05^{c}	818.62±0.04^{a}	2111.59±0.42^{b}
Palmyra	1333.66±0.05^{e}	2201.80±0.04^{c}	2571.51±0.23^{b}	617.55±0.01^{a}	2647.19±1.03^{d}

Standard deviation for three replicate (n=3) determinations. Means with the same letters on the same raw are not significantly different at α= 0.05

Table 2: Total phenolic content (TPC) (mg of gallic acid/100g) of dehydrated beal and palmyra

parameter	Fruit	Solar drying x̄±SD	Oven drying x̄±SD	Freeze prior to drying x̄±SD	Sun drying x̄±SD	Vacuum drying x̄±SD
(TPC) (mg/GAE /100g)	Beal	.65.0 ±0.12^{d}	11.85±0.27^{c}	12.62±0.12^{b}	10.42±0.16^{e}	16.67±0.11^{a}
	Palmyra	5.57±0.06^{cd}	5.87±0.07^{c}	6.27±0.08^{b}	5.41±0.07^{d}	7.32±0.06^{a}

Standard deviation for three replicate (n=3) determinations. Means with the same letters on the same raw are not significantly different at α= 0.05

The fruit powders obtained from five types of drying methods were analyzed for β -Carotene shown in Table 1.The peaks for β -Carotene were recorded at 4 to 5 min, as the peaks obtained at 4.6 min in standard. The results are in conformation with the findings of Ahamad *et al.* 2007 [10] standard beta carotene peak was achieved at the retention time of 4.7 min. Among the drying methods such as; vacuum drying, drying using lab scale air oven, drying after freezing (Freeze for one hour followed by mechanical drying), solar drying and sun drying showed the β - Carotene concentration ranging from 818.62 µg/100g to 2111.59 µg/100g and 617.55 µg/100g to 2647.19 µg/100g in beal and palmyra respectively. Among different treatments tested the highest concentration of β -Carotene was recorded in vacuum dried samples both in beal and palmyra fruit powders it may be due to low temperature applied during drying process. The results obtained results obtained from the study were supported that fruits and vegetables in dried form are a good source of energy, mineral and vitamins. However during the process of dehydration, there are possibilities to changes in nutritional status of the products [11]. A more number of vitamins such as A, C and thiamin are heat sensitive and sensitive to oxidative degradation. The total phenolic content (TPC) of different food powders were significantly difference (α< 0.05) among five drying treatments employed (table 2). The sun drying treatment was significantly affect for retention of phenols and it was recorded the lower retention compared to other treatments in both fruit powders tested. The vacuum drying performed best by retaining of higher TPC.

Determination of antioxidant composition of dehydrated vegetables

β -Carotene and total phenolic content of dehydrated pumpkin and total anthocyanin content of hibiscus with different drying methods are given in table 3.

Table 3: β -Carotene content (mg/100g) ,Total phenolic content (TPC) (mg of gallic acid (GA)/1g) and anthocyanin content of dehydrated vegetables

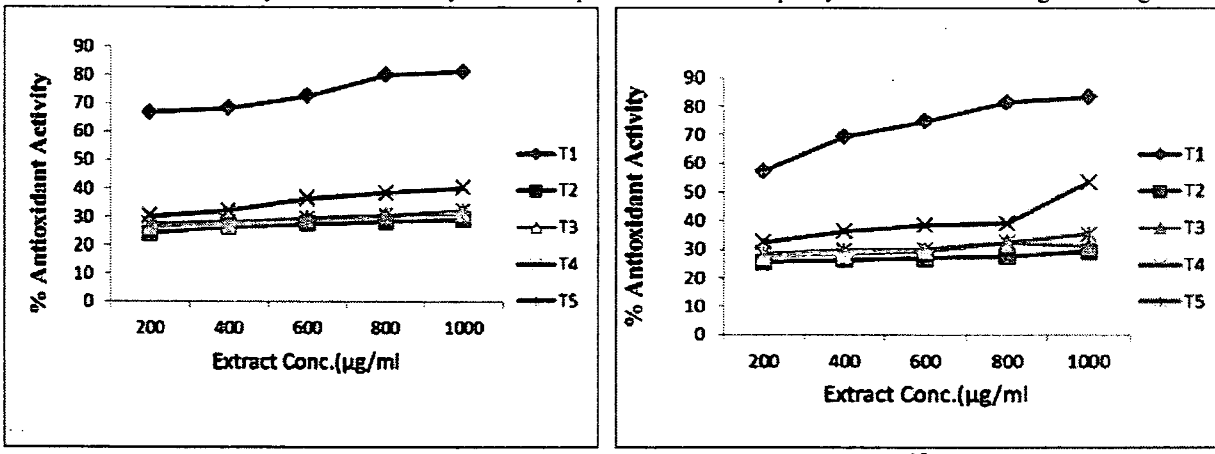
product	Parameter	Solar drying x̄±SD	Oven drying x̄±SD	Freeze prior to drying x̄±SD	Sun drying x̄±SD	Vacuum drying x̄±SD
Pumpkin	β carotene(µg /100g)	20.23±0.01	29.0±0.02	32.6±0.04	18.4±0.01	38.7±0.02
	(TPC) (mgGA /g)	0.01±0.01	0.02±0.11	0.02±0.02	0.01±0.02	0.06±0.03
Hibiscus	Anthocayanin (mg/100g)	108.88±0.1	0.31±0.07	209.64±0.05	91.66±0.05	215.19±0.53

Standard deviation for three replicate (n=3) determinations.

Among different treatments tested the higher concentration of β -Carotene was recorded in vacuum dried sample (table 3). The total phenolic content (table 3) of dehydrated pumpkin powder was higher in vacuum dried sample and it was significantly different (α< 0.05) from other treatments employed. The sun drying and solar drying treatments were significantly affect for retention of phenols and it was recorded the lower retention compared to other treatments. Ozgur et al., 2011[12] reported that, the fresh leeks had higher phenolic contents (116.43 mg rutin eq. 100 g) when compared to the dehydrated samples (26.33 mg rutin eq 100 g), which may be due to the breakdown of phenolics during dehydration [13]. Meyer *et al.* 1998 [14] stated that the antioxidant activities of phenolics in different vegetables markedly vary and may be due to the differences in the phenolic compound structures primarily related to their hydroxylation and methylation patterns. Oven dried samples showed higher level of ash and fiber content but less in protein. Vacuum drying was identified as the most effective drying technique can be use to preserve anthocyanin during dehydration when compared to other treatments. With regarding to total anthocyanin content, higher level was recorded by vacuum dried sample (107.5±0.45) followed by the solar drying (94.26±0.07) may be the reason due to application of low heat under short time period (table 3).

Determination of the antioxidant activity of dehydrated fruit powders

The DPPH antioxidant assay was done for dehydrated fruit powders of beal and palmyra and outcome was given in fig 1.



1a. **1b.**

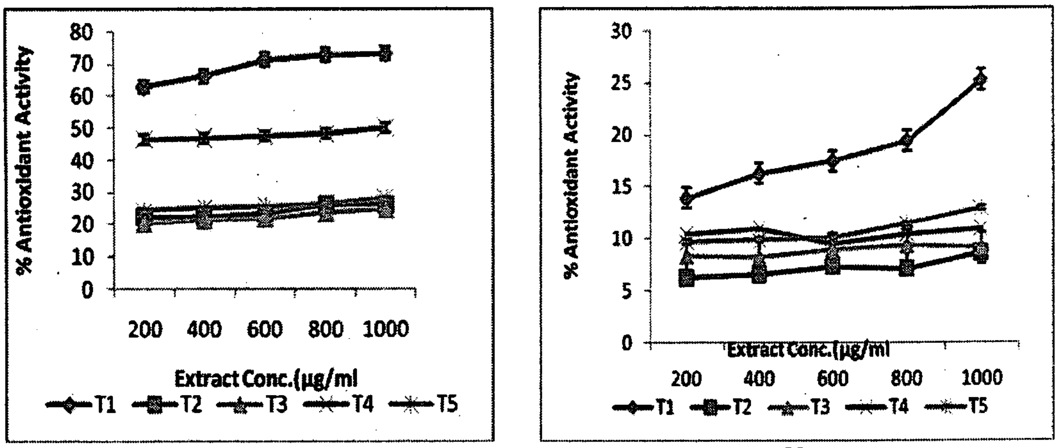
Figure 1: DPPH radical scavenging , 1a- Dehydrated Bael (*Aegle marmelos).* 1b- Palmyra (*Borassus flabellifer)* fruit powders T1: Vacuum drying; T2: Sun drying; T3: Solar drying; T4: Freeze for one hour prior to drying in lab scale air oven; T5: Drying using lab scale air oven

The DPPH radical scavenging assay is an easy rapid and accurate method for determine the antioxidant activity in plant extracts. Among number of methods available, using 1, 1-diphenyl-2-picryl hydrazyl radical (DPPH) has received the maximum attention owing to its ease of use and its convenience. The DPPH scavenging activity was done methanol as a solvent. In the present study the radical scavenging activity of vacuum dried beal fruit powder recorded the highest scavenging activity ranged from 66.87% -81.33% at the concentration 200- 1000 µg/ml of extracts and lowest was recorded by sun dried sample that was given the scavenging activity ranged from 24.31% - 29.21% at the concentration 200- 1000 µg/ml of extracts (Figure 1a). The radical scavenging activity of vacuum dried palmyra fruit powder recorded the highest scavenging activity ranged from 57.32% - 83.25% at the concentration 200- 1000 µg/ml and the lowest was given by sun dried fruit powder (Figure1b). Vacuum dried fruit powders of palmyra and beal were given highest radical scavenging activity and the scavenging activity of palmyra fruit powder is higher than the beal (Figure 1).

Determination of the antioxidant activity of dehydrated vegetables

The DPPH antioxidant assay was done for dehydrated vegetable powders of pumpkin and hibiscus was given in figure 2. The study revealed that radical scavenging activity of vacuum dried pumpkin and hibiscus powder recorded the highest scavenging activity ranged from 62.95% - 73.19% and 13.86% - 25.26% respectively at the concentration 200- 1000 µg/ml of extracts and lowest was recorded by sun dried samples that was given the scavenging activity 13.86% - 25.26% and 6.22% - 8.64% respectively (Figure 2a) .

The study revealed that the radical scavenging activity of vacuum dried hibiscus powder recorded the highest scavenging activity ranged from 13.86% - 25.26% at the concentration 200- 1000 µg/ml of extracts and lowest was recorded by sun dried samples that was given the scavenging activity 6.22% - 8.64% (Figure 2b).



2a 2b

Figure 2: DPPH radical scavenging activity 2a- Dehydrated pumpkin 2b -Dehydrated hibiscus
T1: Vacuum drying; T2: Sun drying; T3: Solar drying; T4: Freeze for one hour prior to drying in lab scale air oven; T5: Drying using lab scale air oven

CONCLUSION

Higher retention of antioxidants such as β–Carotene, anthocyanin and total phenolics were recorded in vacuum dried fruits and vegetables and it was significantly difference ($\alpha = 0.05$) from other drying treatments employed. It was found that the highest level of phenolic compounds, β–Carotene and total anthocyanin content and the antioxidant activity (DPPPH assay) of dehydrated fruits and vegetables depend on exposure time, temperature and processing conditions. It was revealed that during dehydration process the antioxidant activity was decreased and the higher antioxidant activity was observed in vacuum dried fruits and vegetable powders. The lower retention was observed in sun dried sample may be due to expose of long time in high temperature. Vacuum drying can be recommended as the most effective drying method to protect antioxidant properties of fruit and vegetable powders than other drying treatments.

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Ministry of Higher Education Higher Education for the 21st Century Project

16th November 2015

Dean

Faculty of Applied Sciences,

University of Sri Jayewardenepura.

Dear Madam/ Sir,

Participation at the Stakeholder Workshop on Programme Review Manual on 16th- 17th October, 2015

Dr. S.B. Navaratne

I wish to inform you that Dr. S.B. Navaratne nominated to represent the Faculty of Applied Sciences at the Stakeholder workshop held on 16th and 17th October 2015, to obtain the views of the Faculties on ***Draft Manual: Programme Review***, participated at the workshop and actively contributed to the final outcome.

Thank you for nominating Dr. S.B. Navaratne.

Sincerely,

Prof. Kalyani Perera
QA Consultant (universities)/ HETC

Cc. Dr. S.B. Navaratne

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