

Effect of Drying Methods and Type of Packaging Materials on Phytochemical Content and Total Antioxidant Capacity of Five Medicinal Plants with Cosmetic Potential over Three Months Storage at Ambient Temperature

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Abstract Drying and storage are the most integral parts of the post-harvest practices of herbal materials. These practices directly influence the physical and chemical quality of the processed product. Therefore, the main objective of the present study was to analyze the effect of drying methods and packaging materials on total flavonoid content, total phenolic content, and total antioxidant capacity of five medicinal plant leaves with cosmetic potential. Leaves of *Hibiscus rosa-sinensis* L., *Senna alata* (L.) Roxb., *Centella asiatica* (L.) Urb., *Ocimum tenuiflorum* L. and *Justicia adhatoda* L. were dried to a constant weight using shade drier at 30-35°C, solar drier at 30-40°C and oven at 40°C. Thereafter, dried leaves were stored using three different packaging materials namely glass jars, polythene bags and gunny bags at ambient temperature for three months. Aluminum chloride colorimetric assay, folin-ciocalteau method, and phosphomolybdate assay were employed to analyze the total flavonoid content (TFC), total phenolic content (TPC) and total antioxidant capacity (TAC) of ethanolic extracts of leaves respectively in each month. Data were presented as mean \pm standard deviation of minimum three replications. Significant interactions of the drying methods and packaging materials on TAC, TFC and TPC of dried leaf materials were analyzed using Two-way ANOVA. Results showed that the maximum TFC, TPC and TAC in oven dried *H. rosa-sinensis* (23.48 \pm 2.49 mg RE/100g DW, 1.09 \pm 0.24 mg GAE/100g DW and 0.39 \pm 0.05 mg AAE/100g DW respectively) and *C. asiatica* (128.64 \pm 10.59 mg RE/100g DW, 2.38 \pm 0.32 mg GAE/100g DW and 2.2 \pm 0.05 mg AAE/100g DW respectively) leaves stored in glass jars and solar dried *S. alata* (117.43 \pm 9.00 mg RE/100g DW, 3.99 \pm 0.29 mg GAE/100g DW and 1.07 \pm 0.04 mg AAE/100g DW respectively), *O. tenuiflorum* (216.02 \pm 0.75 mg RE/100g DW, 1.92 \pm 0.12 mg GAE/100g DW and 1.07 \pm 0.03 mg AAE/100g DW respectively) and *J. adhatoda* (11.13 \pm 1.23 mg RE/100g DW, 1.02 \pm 0.19 mg GAE/100g DW and 0.42 \pm 0.04 mg AAE/100g DW respectively) leaves stored in glass jars at the end of the storage period. However, statistically significant interaction (p value < 0.05) was not reported between drying method and packaging material on TPC of *C. asiatica* and *O. tenuiflorum* leaves and TFC of *S. alata* leaves. In conclusion, determining the effect of different processing methods on chemical constituents of aforementioned plant leaf materials is suggested to assure the quality of the final product.

Keywords: antioxidant capacity, drying methods, medicinal plants, packaging materials, phytochemical content, storage

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1. Introduction

The post-harvest process has great influence on quality assurance of medicinal plant materials in the productive chain. Among the post-harvest processes, drying and storage are essential to maintain the product with the physical and chemical characteristics closer to its fresh state. Failures in any of these steps influence the quality of the final product [1]. Drying is the fundamental and generally used method for post-harvest preservation of medicinal plants. It allows the quick conservation of the medicinal qualities of the plant material while enhancing shelf life of plant materials and reducing the risk of microbial attacks [2]. Conventionally, low drying temperatures between 30°C and 50°C are recommended to protect sensitive active ingredients [3]. But drying temperature is determined based on plant parts. For an instance, the air temperature is kept at 20 - 40°C for thin materials like leaves but is often elevated to 60 - 70°C for hard plant parts such as roots and barks. During the drying process, rapid removal of the water from the cells of plant materials will prevent the enzymatic degradation of the cell constituents, thus augmenting the shelf life of the plant materials during storage. However, to halt the enzymatic activities, the water content must be brought down to about 10% [4].

Good Storage Practices of raw drugs are very imperative as it plays a pivotal role in safety, efficacy and quality of the finished products [4]. The storage of medicinal plants has the purpose of avoiding the deterioration of its quality, maintaining the qualitative and quantitative aspects after drying, by the development of ideal conditions of temperature and relative humidity, avoiding the attack of microorganisms, fungi and insects during the period of storage [1]. In order to expand the shelf life of processed plant materials, it is essential to store them in a dry condition in carefully closed containers in dark place [4]. It enhances the stability of crude drugs by excluding the direct impacts of oxygen, light, microbes and insects on crude drugs [4,5]. Further, it is crucial to prevent the remoistening of dried material by keeping relative humidity in the storage room at a suitable level [3]. Masand *et al.* [5] stated all the raw herbal drugs should be stored at a cool place where temperature is between 8 - 25°C. Another important factor to be considered in the storage of medicinal plants is the type of packaging. Lisboa *et al.* [1] recommended that paper bags, polyethylene bags, cardboard boxes and paper bags type double kraft with an inner layer of non-toxic polyethylene are the most suitable packaging materials for storing leaves. However, raw herbal drugs require a series of extended studies that aim on establishing the safety and efficacy of finished herbal drugs by changing or improving drying and storage practices of raw herbs used in plant-based industries [5].

As an emerging plant - based industry in Sri Lanka, herbal cosmetic industry is facing several challenges at present. Of these, inadequacy of quality raw materials is the key challenge. This may result of the lack of standards for post-harvest practices of herbal materials in terms of drying and storage [6]. Therefore, the aim of this present study was to determine the impact of different drying methods and different types of packaging materials on

total flavonoid content, total phenolic content, and total antioxidant capacity of *Hibiscus rosa-sinensis* L., *Senna alata* (L.) Roxb., *Centella asiatica* (L.) Urb., *Ocimum tenuiflorum* L. and *Justicia adhatoda* L., leaves with cosmetic potential over three months storage period at ambient temperature.

2. Methodology

2.1. Collection of Plant Materials

Fresh leaves of *Hibiscus rosa-sinensis* L., *Senna alata* (L.) Roxb., *Centella asiatica* (L.) Urb., *Ocimum tenuiflorum* L. and *Justicia adhatoda* L. were collected from Chilaw, North Western province, Sri Lanka. Collected leaves were sorted and washed with running water. Thereafter, washed leaves were drained completely on paper towels. Then, each leaf sample was divided into 3 batches.

2.2. Drying and Storage of Herbal Materials

Three different methods were employed for drying leaves.

2.2.1. Oven Drying

Leaves were dried at 40 °C in a laboratory oven (OF-22G, Jeio Tech, Korea). Evenly distributed leaves on perforated stainless-steel trays were dried until it reached to a constant weight.

2.2.2. Solar Drying

Fabricated solar dryer equipped with forced air circulation system was used to dry leaves. Inside temperature was ranged from 30 - 40°C during the daytime. Samples were placed uniformly on perforated trays and dried until constant weight was achieved.

2.2.3. Shade Drying

Leaves were dried using a fabricated shade drier at ambient temperature ranged from 30 - 35°C without exposing to sun light. Leaves were spread uniformly on perforated trays and dried until leaves reached a constant weight.

2.2.4. Storing the Dried Materials

100 g of each dried leaf sample under three different drying methods was separated into 10 batches. One batch of each leaf variety was used to measure the total flavonoid content (TFC), total phenolic content (TPC) and total antioxidant capacity (TAC) immediately after drying. The remaining 9 batches in each leaf type was stored in three glass bottles, three polythene bags, three gunny bags (10 g per each) and labelled for three months quality analysis.

2.3. Preparation of Crude Extracts

Dried samples were coarsely powdered using mechanical grinder. One gram of powdered sample from each was soaked in 20ml of 80% ethanol (1W:20V) for 24 hours. The extracts were subsequently filtered through a filter

paper (Whatman No. 01; Whatman Paper Ltd, Maidstone, UK). Then filtrate was concentrated under reduced pressure using a centrifugal evaporator (EYELA CVE-3000, Indonesia) to obtain the ethanol extracts. Three replicates were prepared from each packaging type. The prepared extracts were stored at 4 °C until assayed within a week.

2.4. Determination of Total Flavonoid Content (TFC)

The aluminium chloride colorimetric assay was used to determine the total flavonoid content (TFC) as described by Gunathilake *et al.*, [7]. In brief, 0.5 mL of ethanolic extracts of leaf solutions was added to 3 mL of distilled water. Then, 0.3 ml of 5% NaNO₂ was added and stands for 5 min at room temperature (30°C). About 0.3 ml of 10% AlCl₃ was added 5 min later and allows standing for another 6 min, and then 2 ml of 1 M NaOH was added, and the solution was made up to 10 mL with distilled water and mixed. The absorbance was determined at 510 nm against blank using the spectrophotometer (GENESYS 10S UV-VIS). Rutin standard solutions were prepared by dissolving rutin in ethanol at the concentrations ranging from 50 to 250 mg/L. The standard curve of rutin, $y = 0.0118x + 0.0126$ ($R^2 = 0.981$) was used to determine the TFC expressed as milligram of rutin equivalents (RE) per 100 g dry weight of leaves.

2.5. Determination of Total Phenolic Content (TPC)

Folin–Ciocalteu assay was used to determine the total phenolic content (TPC) of extracts as described by Gunathilake and Ranaweera, [8]. About 0.5 mL of extract and 0.1 mL of Folin- Ciocalteu reagent (0.5 N) were mixed and incubated at room temperature for 15 min in the dark. Then 2.5 mL 7.5% sodium carbonate was added to the mixture and further incubated for 2 hours in the dark at room temperature. Thereafter, the absorbance was measured at 760 nm using a spectrometer (GENESYS 10S UV-VIS). Gallic acid standard solutions were prepared by dissolving gallic acid in ethanol at the concentrations ranging from 50 to 250 mg/L. The standard curve of gallic acid, $y = 0.0906x + 0.4804$ ($R^2 = 0.989$) was used to determine the TPC expressed as milligram of gallic acid equivalents per 100 g dry weight of leaves.

2.6. Determination of Total Antioxidant Capacity (TAC)

Phosphomolybdate method was used to determine the total antioxidant capacity (TAC) of extracts as described by Gunathilake and Ranaweera, [8]. The tubes containing leaf extract (0.3 mL) and 3 mL reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate and 4 mM ammonium molybdate) were incubated at 95 °C for 90 min. After the mixture had cooled to room temperature, the absorbance of each solution was measured at 695 nm

spectrophotometrically (GENESYS 10S UV-VIS) against a blank. Ascorbic acid standard solutions were prepared by dissolving ascorbic acid in ethanol at concentrations ranging from 50 to 250 mg/L. The standard curve of ascorbic acid, $y = 0.0657x + 0.1071$ ($R^2 = 0.995$) was used to determine the TAC expressed as milligram of ascorbic acid equivalents (AAE) per 100 g dry weight of leaves.

2.7. Statistical Analysis

Descriptive statistics were used to show the results of total flavonoid content (TFC), total phenolic content (TPC) and total antioxidant capacity (TAC) of leaves immediately after drying under three different methods. Results of the assessment of the effect of three drying methods and three packaging materials of five medicinal plant leaves were presented as mean ± standard deviation of minimum three replications. Significant interaction of the drying methods and packaging materials on TAC, TFC and TPC of dried leaf materials was analysed using Two-way ANOVA. Statistical significance was set at 5%. The programmes used were Microsoft Excel 2016 and Minitab 17.

3. Results and Discussion

As shown in the Table 1, the maximum TFC, TPC and TAC of *H. rosa-sinensis* leaves were reported from the solar dried sample after immediate drying. It was 90.09 ± 2.51 mg Rutin/ 100g DW, 4.39 ± 1.26 mg Gallic/ 100g DW and 17.53 ± 2.09 mg AAE/ 100g DW of leaves, respectively. However, the maximum TFC, TPC and TAC were recorded from the oven dried *H. rosa-sinensis* leaves stored in glass jars at the end of each month. The highest TFC and TPC were about 24 mg Rutin/ 100g DW and 2 mg Gallic/ 100g DW while the maximum TAC was 0.39 mg AAE/ 100g DW of *H. rosa-sinensis* leaves by the end of the trimester. Furthermore, statistically significant interaction was reported between drying method and packaging material on TFC ($p = 0.00$), TPC ($p = 0.00$) and TAC ($p = 0.00$) of *H. rosa-sinensis* leaves.

According to the Table 2, the highest value of TFC and TAC were recorded from solar dried leaf sample of *S. alata* whereas the highest TPC was recorded from the shade dried sample before storage. Those values were approximately 323 mg Rutin/ 100g DW, 40 mg AAE/ 100g DW and 8 mg Gallic/ 100g DW of *S. alata* leaves, respectively. But at the end of the storage period, the maximum TFC, TPC and TAC were reported from solar dried *S. alata* leaves stored in glass jars. It was approximately 117 mg mg Rutin/ 100g DW, 4 mg Gallic/ 100g DW and 1 mg AAE/ 100g DW of *S. alata* leaves, respectively. Moreover, statistically significant interactions were recorded between drying method and packaging material on TPC ($p = 0.011$) and TAC ($p = 0.000$) of *S. alata* leaves excepting for TFC ($p = 0.187$).

Table 1. TFC, TPC and TAC of *Hibiscus rosa-sinensis* L. leaves dried under 03 different drying conditions and stored in three types of packaging materials for three months

Total Flavonoid Content (mg Rutin/ 100g DW)									
	Oven (85.48±1.06)			Solar (90.09±2.51)			Shade (60.54±2.08)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	45.74±4.46	39.67±10.19	22.46±1.79	21.55±5.84	18.42±1.27	31.55±2.10	22.43±4.28	18.96±1.93	25.57±1.46
2nd month	31.81±2.45	31.64±2.42	18.33±0.68	19.83±3.94	17.32±0.72	15.48±0.60	14.75±0.31	14.75±3.64	18.64±0.95
3rd month	23.48±2.49	22.60±2.39	13.70±0.84	16.61±1.36	13.00±0.42	10.25±0.85	9.49±0.55	14.01±0.08	16.19±0.31
Total Phenolic Content (mg Gallic/ 100g DW)									
	Oven (3.88±0.95)			Solar (4.39±1.26)			Shade (3.63±0.82)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	2.57±0.39	2.33±0.31	1.59±0.23	1.28±0.28	1.69±0.40	1.98±0.23	1.53±0.19	1.51±0.22	1.96±0.18
2nd month	2.20±0.26	1.61±0.44	1.27±0.29	1.28±0.25	1.35±0.36	1.93±0.19	0.87±0.51	1.32±0.31	1.51±0.14
3rd month	1.90±0.24	1.49±0.22	1.15±0.18	0.87±0.31	0.93±0.41	1.51±0.28	0.65±0.11	0.68±0.09	0.70±0.08
Total Antioxidant Capacity (mg AAE/ 100g DW)									
	Oven (14.59±1.35)			Solar (17.53±2.09)			Shade (15.69±1.25)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	13.82±3.51	11.20±2.40	9.94±0.53	8.70±0.35	8.50±0.66	13.29±1.22	6.52±0.47	9.77±0.27	10.92±0.87
2nd month	12.20±0.40	9.76±0.31	6.92±0.08	8.58±0.47	8.13±0.43	6.25±0.34	0.66±0.24	0.53±0.10	1.93±0.38
3rd month	0.39±0.05	0.37±0.03	0.03±0.03	0.06±0.03	0.06±0.06	0.22±0.03	0.31±0.14	0.11±0.05	0.16±0.02

Table 2. TFC, TPC and TAC of *Senna alata* (L.) Roxb. leaves dried under 03 different drying conditions and stored in three types of packaging materials for three months

Total Flavonoid Content (mg Rutin/ 100g DW)									
	Oven (230.65±3.18)			Solar (323.19±2.54)			Shade (277.06±2.91)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	157.71±9.53	227.91±18.15	108.16±2.95	157.23±3.59	148.62±7.55	155.20±8.16	235.93±1.37	119.15±3.25	145.51±5.39
2nd month	135.25±6.82	128.08±6.32	94.46±9.04	126.22±2.58	113.25±6.10	123.84±15.52	149.21±10.3	114.18±0.27	131.84±0.16
3rd month	93.81±9.82	112.74±7.55	87.06±5.49	117.43±9.00	81.24±1.30	81.50±1.15	81.30±0.66	107.97±1.15	94.41±0.64
Total Phenolic Content (mg Gallic/ 100g DW)									
	Oven (5.27±1.03)			Solar (7.37±1.19)			Shade (8.44±2.01)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	4.30±0.31	4.56±0.49	4.04±0.39	4.76±0.026	4.37±0.38	6.34±0.76	4.48±1.57	4.01±0.24	4.73±0.37
2nd month	4.05±0.41	4.06±0.38	3.91±0.25	4.67±0.27	3.91±0.26	4.24±0.29	2.94±0.35	2.55±0.07	3.15±0.15
3rd month	3.70±0.34	3.70±0.32	3.11±0.54	3.99±0.29	3.68±0.65	3.58±0.31	1.56±0.08	2.55±0.39	2.57±0.21
Total Antioxidant Capacity (mg AAE/ 100g DW)									
	Oven (32.11±3.42)			Solar (39.78±2.11)			Shade (34.95±1.54)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	24.02±0.48	23.17±0.89	22.13±2.15	24.07±0.87	21.36±1.98	21.39±1.61	28.65±1.33	19.15±0.91	16.20±2.25
2nd month	21.56±2.30	21.54±2.27	21.19±1.89	24.07±0.50	20.95±1.16	21.00±1.69	16.99±0.82	16.85±0.96	15.97±4.28
3rd month	1.02±0.07	0.88±0.03	0.56±0.02	1.07±0.04	0.75±0.07	0.84±0.04	0.65±0.04	0.62±0.02	0.59±0.09

Table 3. TFC, TPC and TAC of *Centella asiatica* (L.) Urb. leaves dried under 03 different drying conditions and stored in three types of packaging materials for three months

Total Flavonoid Content (mg Rutin/ 100g DW)									
	Oven (336.15±5.14)			Solar (390.28±4.39)			Shade (356.29±4.02)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	137.88±0.25	213.7±9.04	158.11±9.24	160.82±6.87	99.49±0.55	119.41±0.30	153.42±1.95	157.77±8.45	116.13±0.47
2nd month	136.5±1.49	181.58±0.51	111.70±1.00	91.07±0.27	86.47±5.31	108.59±1.31	102.23±0.74	72.37±1.53	88.84±4.93
3rd month	128.64±10.59	112.40±18.31	62.40±5.81	85.59±16.26	40.31±10.54	47.71±2.76	22.80±0.80	31.38±0.73	78.00±0.31
Total Phenolic Content (mg Gallic/ 100g DW)									
	Oven (5.71±0.94)			Solar (3.92±1.06)			Shade (4.08±1.64)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	3.59±0.39	3.27±0.37	5.24±0.55	3.07±0.19	3.01±0.33	3.32±1.05	2.26±0.10	2.55±0.25	2.25±0.40
2nd month	3.29±0.19	3.22±0.31	3.04±0.33	2.86±0.30	0.99±0.21	3.17±0.51	1.52±0.18	2.07±0.10	1.66±0.23
3rd month	2.38±0.32	1.99±0.04	1.91±0.03	0.81±0.28	0.29±0.70	1.48±0.13	0.70±0.22	0.85±0.42	1.34±0.17
Total Antioxidant Capacity (mg AAE/ 100g DW)									
	Oven (22.45±2.43)			Solar (23.59±3.44)			Shade (21.05±2.86)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	13.89±0.71	16.59±2.65	9.52±0.58	20.06±0.52	9.23±0.53	8.39±2.06	16.53±1.20	19.04±2.91	12.16±0.79
2nd month	8.90±2.36	7.73±1.27	10.17±0.71	9.47±0.25	9.08±0.45	8.01±0.94	8.19±0.52	10.86±0.22	10.03±0.63
3rd month	2.2±0.05	0.84±0.01	0.33±0.03	0.40±0.06	0.39±0.03	0.49±0.04	0.54±0.02	0.74±0.02	0.56±0.10

Considering the results of TFC, TPC and TAC of *C. asiatica* leaves after immediate drying, the highest value of TFC and TAC was recorded from the solar dried *C. asiatica* leaves while the maximum TPC was reported from the oven dried *C. asiatica* leaf sample. Those values were 390.28±4.39 mg Rutin/ 100g DW, 23.59±3.44 AAE/ 100g DW and 5.71±0.94 mg Gallic/ 100g DW of *C. asiatica* leaves. However, as indicated in the Table 3, by the end of the third month, the maximum TFC, TPC and TAC were recorded from oven dried leaves stored in glass jars. It was about 129 mg mg Rutin/ 100g DW, 2 mg Gallic/ 100g DW and 2 AAE/ 100g DW of leaves respectively. Furthermore, statistically significant interaction between drying method and packaging material on TFC ($p = 0.000$) and TAC ($p = 0.000$) of *C. asiatica*

leaves were reported excluding for TPC ($p = 0.094$).

As demonstrated in the Table 4, the maximum TFC, TPC and TAC were reported from solar dried *O. tenuiflorum* leaves just after immediate drying. It was reported as 688.84±10.61 mg Rutin/ 100g DW, 6.58±1.66 mg Gallic/ 100g DW and 34.82±2.91 mg AAE/ 100g DW of *O. tenuiflorum* leaves, respectively. At the end of the storage period, the maximum TFC, TPC and TAC were reported from solar dried *O. tenuiflorum* leaves stored in glass jars. It was about 216 mg Rutin/ 100g DW, 2 mg Gallic/ 100g DW and 1 mg AAE/ 100g DW of leaves, respectively. Moreover, interaction between the drying method and packaging material was statistically significant on TFC ($p = 0.002$) and TAC ($p = 0.000$) of *O. tenuiflorum* leaves excepting for TPC ($p = 0.305$).

Table 4. TFC, TPC and TAC of *Ocimum tenuiflorum* L. leaves dried under 03 different drying conditions and stored in three types of packaging materials for three months

Total Flavonoid Content (mg Rutin/ 100g DW)									
	Oven (410.32±6.15)			Solar (688.84±10.61)			Shade (568.29±7.27)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	261.61±3.53	395.79±5.35	165.03±9.82	389.10±22.14	401.05±4.06	350.71±13.18	406.55±10.09	397.79±13.24	217.06±1.62
2nd month	215.68±17.80	296.72±17.10	155.40±17.2	363.19±11.78	387.40±13.30	274.94±12.36	198.87±15.60	182.15±9.19	192.71±1.91
3rd month	128.84±0.59	145.85±3.65	135.62±0.62	216.02±0.75	197.01±2.16	213.54±10.46	137.01±1.05	165.2±4.07	177.71±4.67
Total Phenolic Content (mg Gallic/ 100g DW)									
	Oven (6.05±0.28)			Solar (6.58±1.66)			Shade (4.32±1.03)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	2.90±0.36	3.67±0.39	2.27±0.51	3.68±0.36	3.88±0.24	4.04±0.44	2.98±0.04	3.11±1.35	3.40±2.15
2nd month	2.10±0.20	2.49±0.08	1.45±0.27	3.31±0.44	2.98±0.36	2.65±0.43	2.41±0.15	2.78±0.54	3.03±0.29
3rd month	1.49±0.26	1.78±0.10	1.33±0.25	1.92±0.12	1.89±0.08	1.80±0.20	0.90±0.14	1.19±0.13	0.70±0.20
Total Antioxidant Capacity (mg AAE/ 100g DW)									
	Oven (23.68±1.55)			Solar (34.82±2.91)			Shade (28.66±2.15)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	19.09±0.72	19.28±0.63	15.07±0.71	24.27±0.51	18.91±0.61	18.53±0.91	19.19±1.00	29.71±1.16	16.40±0.73
2nd month	12.71±2.15	17.37±0.40	8.45±0.16	7.64±1.87	17.85±1.52	11.69±1.16	17.80±0.57	15.57±0.48	11.39±0.89
3rd month	0.66±0.03	0.58±0.05	0.60±0.05	1.07±0.03	0.93±0.06	0.88±0.06	0.45±0.01	0.38±0.05	0.39±0.06

Table 5. TFC, TPC and TAC of *Justicia adhatoda* L. leaves dried under 03 different drying conditions and stored in three types of packaging materials for three months

Total Flavonoid Content (mg Rutin/ 100g DW)									
	Oven (82.56±1.36)			Solar (69.94±1.06)			Shade (95.62±0.95)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	13.36±3.71	10.71±0.34	16.44±0.93	18.84±6.54	8.87±1.91	10.82±0.20	23.33±0.77	10.25±0.59	19.75±0.52
2nd month	11.36±0.76	12.15±0.98	15.20±1.03	13.36±0.07	6.44±0.60	10.03±0.72	21.84±2.96	9.41±0.11	7.49±0.08
3rd month	10.62±0.17	7.83±0.13	7.80±0.07	11.13±1.23	5.57±0.21	5.93±0.14	7.88±0.21	9.27±0.72	5.20±0.18
Total Phenolic Content (mg Gallic/ 100g DW)									
	Oven (2.69±0.67)			Solar (3.64±0.95)			Shade (3.22±0.48)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	1.27±0.43	1.96±0.13	1.58±0.33	1.87±0.25	1.21±0.47	1.95±0.05	2.20±0.33	1.73±1.12	0.92±0.45
2nd month	1.26±0.19	1.15±0.17	1.93±0.21	1.53±0.22	0.87±0.26	1.21±0.21	0.80±0.16	1.29±0.45	0.11±0.11
3rd month	0.40±0.24	0.50±0.01	0.53±0.05	1.02±0.19	0.13±0.22	0.13±0.19	0.31±0.18	0.22±0.28	0.25±0.06
Total Antioxidant Capacity (mg AAE/ 100g DW)									
	Oven (25.11±1.38)			Solar (24.53±2.65)			Shade (20.64±1.57)		
	Glass	Polythene	Gunny	Glass	Polythene	Gunny	Glass	Polythene	Gunny
1st month	12.95±0.65	13.69±0.37	12.69±0.42	16.32±2.82	8.48±0.64	10.03±1.06	13.33±1.06	19.78±2.71	9.60±0.84
2nd month	2.59±0.16	9.58±1.26	4.24±0.60	3.17±0.15	3.71±0.63	1.41±0.48	11.36±0.33	15.56±2.19	4.73±0.38
3rd month	0.26±0.03	0.09±0.05	0.10±0.03	0.45±0.04	0.26±0.04	0.30±0.14	0.09±0.01	0.07±0.01	0.09±0.02

In contrast, *J. adhatoda* showed the maximum TFC in shade drying samples, the highest TPC in solar dried leaves and the maximum TAC in oven dried leaves after immediate drying. Those values were 95.62 ± 0.95 mg Rutin/ 100g DW, 3.64 ± 0.95 mg Gallic/ 100g DW and 25.11 ± 1.38 mg AAE/ 100g DW of *J. adhatoda* leaves, respectively. By the end of the third month, the highest TFC, TPC and TAC were reported from the solar dried leaves stored in glass jars. It was about 11 mg Rutin/ 100g DW of leaves, 1 mg Gallic/ 100g DW and 0.5 mg AAE/ 100g DW of *J. adhatoda* leaves, respectively. Further, statistically significant interaction was reported between drying method and packaging material on TFC ($p = 0.00$), TPC ($p = 0.00$) and TAC ($p = 0.00$) of *J. adhatoda* leaves.

Considering the results of TFC, TPC and TAC values of 05 plant leaf materials with cosmetic potential after immediate drying, TFC was comparatively high in *O. tenuiflorum* leaves while TPC and TAC were high in *S. alata* leaves than other plant leaf materials. Overall, results showed higher TFC, TPC and TAC of solar dried leaves of *H. rosa-sinensis* and *O. tenuiflorum* in comparison with oven drying and shade drying methods. Solar dried *S. alata* and *C. asiatica* leaves showed high TFC and TAC while TPC was high in shade dried leaves of *S. alata* and oven dried leaves of *C. asiatica* respectively. In contrast, shade dried *J. adhatoda* leaves showed the maximum TFC while solar dried showed the highest TPC. However, the maximum TAC was recorded from the oven dried *J. adhatoda* leaves. These results are in agreement with the study conducted by Gamage *et al.* [9].

Packaging protects herbs from the growth of microorganism, browning and moisture accumulation, etc. The final quality of the product depends on the drying method, type of packaging material and storage environment [10]. In general, results of this study disclosed high TFC, TPC and TAC in oven dried *H. rosa-sinensis*, *C. asiatica* leaves and solar dried *S. alata*, *O. tenuiflorum*, and *J. adhatoda* leaves stored in glass jars by the end of the storage period. Moreover, TFC and TPC of all plant leaf materials dried under oven, solar and shade have been gradually depleted throughout the storage period in each packaging material. Although, TAC of all plant dried leaves under three different drying methods was considerably high in all packaging materials in the first and second months, it has steadily decreased by the end of the third month. During the study, packed dried leaf materials were stored in a room where room temperature and relative humidity (RH) were highly subjectable to the changes with the external environment. Neither glass jars nor polythene bags were airtight but kept in closed containers. Trapped air inside the glass jars was considerably low in comparison with polythene bags after filling the leaf materials. Thus, high TFC, TPC and TAC of oven dried leaf materials stored in glass jars may be due to the result of rapid inactivation of degradative enzymes during the drying and less exposure to the oxygen during storage period [5,11]. Inferior quality of shade dried leaves stored in polythene and gunny bags may be due to the longer period of drying and contaminations during the shade drying. Moreover, long

term exposure of dried leaf materials to oxygen during drying as well as inside the packaging materials such as gunny bags may result in increasing the redox activity of plant materials and degradation of phenolic compounds [12]. Further, uncontrollable RH in the storage room may result the remoistening of dried materials in gunny bags [3]. When a product is placed in an environment at an uncontrollable temperature and RH, it will affect the equilibrium moisture content (EMC) between the product and the environment. Exposing the dried plant materials to the high RH environment for an infinite period may result the remoistening. Thus, it will lead to the deterioration of plant materials due to the growth of microorganisms [13] and biotransformation of secondary metabolites [14] by activating the degradative enzymes which are widely present in plant tissues such as lipoxygenase and polyphenol oxidase (PPO) [15]. Ultimately, diphenols are oxidised with the presence of oxygen and causing rapid enzymatic oxidation of natural antioxidants [16]. PPO plays an important role in the degradation of phenolics and flavonoids of crops. However, as Ghasemzadeh *et al.* (2016) mentioned, PPO shows variable activity under different storage conditions and its activity is dependent on the drying method of samples, storage, and processing conditions.

4. Conclusion

Considering the TFC, TPC and TAC of plant leaf materials over the three months storage period, the best combination of drying method and packaging material would be oven drying and glass jars for *H. rosa-sinensis* and *C. asiatica* leaves while solar drying and glass jars would be ideal for *S. alata*, *O. tenuiflorum* and *J. adhatoda* leaves. However, the information and comprehensive research on the influence of drying methods and packaging materials of herbs on bio-active compounds is still lacking. Thus, shelf-life evaluation of herbs is one of key areas to be addressed in future through comprehensive research to unleash the true potential of medicinal plants during post-harvest processing. Different processing methods cause variations in the chemical constituents and biological activity of medicinal plant materials. Thus, determining the effect of post-harvest treatment on chemical constituents and biological activity of medicinal plant materials is key to improve for the quality control. Moreover, conducting efficacy/ safety tests on medicinal plant ingredients are important to ensure the physical and analytical characteristics of raw materials used for the production up to the standard.

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