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Standardization of post-harvest technology for *Gymnema sylvestre* and *Plectranthus forskohlii* (Wild) Briq (Syn: *Coleus forskohlii*)

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Abstract
Experiments were conducted at Medicinal Plants Unit, Horticultural College and Research Institute, Coimbatore to standardize the drying and storage technology for gymnema and medicinal coleus. The leaves of Gymnema were subjected to different drying treatments viz., sun drying, shade drying, initial sun drying and subsequent shade drying and shade drying followed by sun drying. Likewise, the harvested tubers of Coleus were cut into slice of different thickness (0.5, 1.0 and 2.0 cm) and dried in two methods *viz*., sun drying and mechanical drying. Observations were recorded on drying time, drying rate and alkaloid contents in both the crops. In gymnema, drying under open sun light took the lowest time for drying ie., 14 hrs/300g, followed by, shade drying followed by sun drying (20 hrs) and sun drying followed by shade drying (28 hrs). While drying the Gymnema leaves under shade required longer time (32 hrs) than other methods. The highest drying rate was observed in sun drying (0.276g/min) method. The highest gymnemic acid content (344.25 mg $100g^{-1}$) was recorded in shade dried leaves. In coleus, sun drying of 0.5 cm slice thickness registered 18 hrs for attaining 8% moisture level. While in mechanical drying method, drying at 60ºC of 0.5cm slice tubers took the lowest time for drying ie. 360 min/100g with a drying rate of 0.370 g/min. The drying rate was found to be the lowest in sun drying of 2cm slice with a value of 0.065 g/min. The highest forskolin content (0.68%) was recorded in mechanical drying of 0.5 cm slice thickness at 40 °C. Storage studies indicated that irrespective of the crop under study, the dried sample packed in polyethylene lined gunny bag retained the highest alkaloid content and the rapid deterioration was recorded when stored under ambient conditions.

Keywords: Gymnema, medicinal coleus, drying & storage, gymnemic acid, forskolin

Introduction
Complementary and alternative medicine are gradually being integrated into comprehensive treatment plans alongside orthodox methods of diagnosis and treatment. The industrial demand on medicinal plant resources is poised to increase owing to the worldwide buoyancy in the herbal sector engaged in production of herbal health care formulations; herbal based cosmetic products and herbal nutritional supplements. In India, nearly 9,500 registered herbal industries and a multitude of unregistered cottage-level herbal units depend upon the continuous supply of medicinal plants for manufacture of herbal medical formulations based on Indian Systems of Medicine. It is estimated that more than 6,000 higher plant species forming about 40% of the higher plant diversity of the country are used in its codified and folk healthcare traditions (Ved and Goraya, 2007) [24].

The growing demand for medicinal species indicates the emergence of a market with high potential for consumption, requiring a consistent and readily available supply of high quality raw material. The post-harvesting process of medicinal plants has great importance in the production chain, because of its direct influence on the quality and quantity of the active ingredients in the product sold. The industrial growth of medicinal plants is curtailed by a distinct lack of understanding of the specific post-harvest handling and packaging needs of the broad range of species and varieties. Freshly harvested medicinal plants occupy large volumes and pose difficulty in transportation and storage. For handling and storage purposes, reducing the water content of freshly harvested medicinal plants is imperative. By reducing the water content, the material becomes easier to handle and less prone to microbial degradation. The water content is usually removed through thermal drying. The methods available for drying medicinal plants can be grouped into natural and mechanical drying on the basis of heat source or energy utilization (Cai *et al*., 2004) [2]. Recent surveys indicate that poor post-harvest

handling and a lack of knowledge on suitable packaging systems for herbs as the major factors contributing to wastage, poor quality and limited market opportunities. Under these circumstances, it is appropriate to standardize the post-harvest drying and storage practices for economically important medicinal plants like gymnema and medicinal coleus which contribute to the growth and sustenance of herbal industries substantially.

Materials and methods

The experiment was conducted at the Medicinal Plants Unit, Horticultural College and Research Institute, TNAU, Coimbatore. The harvested gymnema leaves were subjected to methods of drying procedures viz., sun drying, shade drying, initial sun drying for 3 hours followed by subsequent shade drying and shade drying for 24hrs followed by sun drying. Sun drying was carried out under open sun from 10 A.M. to 5 P.M with frequent turning of the sample. During this period, the plant samples were weighed at one hour interval. After the attainment of constant weight, the process of sun drying was completed. Likewise, shade drying was carried out under room (ambient) temperature with frequent turning of the sample. During this period of time, at every one hour interval, the plant samples were weighed and expressed in grams. In coleus, the harvested tubers were cut into slices of different thickness (0.5, 1.0 and 2.0 cm) as per the requirement for the specific treatment and dried in two methods *viz*., i) sun drying and ii) mechanical drying. In sun drying method, the tuber pieces were spread uniformly in the aluminum trays and kept open to the sun from 8.30 am to 4.30 pm. The temperature during sun drying ranged from 29 to 34 °C and in the night hours, samples were kept in plastic covers to prevent re-absorption of moisture. Whereas in mechanical drying, the tuber pieces were spread uniformly in the hot air oven at temperatures 40 ºC, 50 ºC and 60 ºC respectively. The samples were weighed at regular intervals and drying was terminated, when the moisture content of the samples attained 8 to 10 per cent. Observations were recorded on drying time, drying rate and alkaloid contents in both the crops. Drying rate was found for all the treatments using the method described by Narasimhan and Johnson (1972) [11].

The quality attributes, total gymnemic acid (*Gymnema sylvestre*) was estimated as per the methods suggested by Rajpal (2002) [19]. About 3.00 gm of the leaf extract was weighed into a beaker. 10% of hydrochloric acid was added to the filtrate to make the pH 1.5. Later the filtrate was distilled with water and the precipitate dissolved in 20ml of 80.0% v/v ethanol or methanol. Filtrate was dried at 70 ºC to a constant weight and percentage of total gymnemic acid was calculated. Forskolin present in the tubers of *Plectranthus forskohlii* was determined by High Performance Thin Layer Chromatography (HPTLC). Standard forskolin and other samples were spotted on pre-coated silica gel plates as narrow bands of 4 mm width at a constant rate of 8 µl sec^{-1} using a Camag Linomat IV model applicator under nitrogen atmosphere. A mixture of benzene and ethyl acetate (85:15 v/v) was used as the mobile phase. The length of the chromatogram of 90 mm and 15 min was required for each run. The plates were sprayed with anisaldehyde sulphuric acid reagent (0.5 ml anisaldehyde + 1 ml H_2SO_4 + 50 ml acetic acid) and heated at 110 °C for 5 min. Orange fluorescence observed at 366 nm was optimally detected and quantified at 315 nm using the Camag TLC scanner with CATS 3.17 software for quantification of the separated compounds in the chromatogram (Malathy and Pai, 1999) [10].

In storage experiment, the shelf life extension with enhanced alkaloid contents were determined using different storage containers viz., jute gunny bags, polythene lined gunny bags, ventilated polythene lined gunny bags and storage at ambient conditions. The statistical scrutiny of data was done by adopting the standard procedures of Panse and Sukhatme (1985) [13]. The critical difference was worked out for 5 per cent level of significance.

Results and discussion

1. Drying experiments

A. Drying time

In Gymnema, the total time required for attainment of constant dry weight of the samples (300 g) was calculated. The results revealed that drying under open sun light recorded the lowest time of drying ie., 14 hrs/300g. While drying the leaves under shade required longer time (32 hrs) than other methods (Table 1). In general, sun drying leads to contamination with foreign inert materials and wide exposure to environmental factors, which ultimately result in unhygienic product quality favouring microbial contamination. Compared to sun drying, the retention of green colour of the leaves, which is necessary for fetching premium prices in the market, was found to be high in the sample dried under ambient temperature (Shade drying). The poor colour of the sun dried samples was due to thermal degradation of chlorophyll pigment under high temperatures. Similar results were reported by Subha Vasugi (2007) [22] in *Cassia angustifolia* and Yuvaraj (2007) [26] in *Wedelia chinensis* respectively.

In *Plectranthus forskohlii*, sun drying of 0.5cm slice thickness recorded the lowest (18 hrs) time for drying (Table 3). While in the mechanical drying method, drying at 60 ºC of 0.5cm slice thickness took lowest time for drying ie. 360 min/100g (Table 4). The results indicated that high temperature (60 °C) increased the rate of moisture removal per unit time and reduced the overall drying time when compared to drying under ambient conditions. Similar results was reported by Rajangam (2006) [17] in *Plectranthus forskholii.*

B. Drying rate

The rate of drying was significantly influenced by different methods of drying. In Gymnema, maximum drying rate was observed in sun drying which recorded the value of 0.276g/min. This was followed by sun drying followed shade drying which recorded 0.236g/min. With respect to sun drying, the rate of drying was greater during initial stages, and it was drastically reduced later, when the moisture level approached the equilibrium (Table 1). This is in accordance with the results of Gupta and Pareek (1993) [6]. in horticultural crops. The drying rate was found to be high in the afternoon hours due to higher solar intensity. The drying rate was found to be the lowest in shade drying with a value of 0.148 g/min. It could be reasoned that in shade drying, the highest final moisture content was exhibited, due to the less temperature which is not enough to remove the moisture. This finding is in accordance with the observations of Fadel and EL Massry (2000) [5]. in rosemary and Cesare *et al.*, (2001) [3]. in *Ocimum* and sage.

In medicinal coleus, the highest drying rate (0.370 g/min) was observed in mechanical drying at 60 ºC with 0.5cm slice thickness when compared to the tubers dried at 40^{O} and 50°C (Table 4). The results indicated that high temperature (60 °C) increased the rate of moisture removal per unit time and reduced the overall drying time. This finding is in accordance with Ranganath and Dubash (1981) [20]. in potato, Yoshikawa

et al., (1994) [25]. in *Alismatis*, and Liu Zhi Jun *et al*. (1998) [9]. in Camptotheca, who reported similar observations with regard to influence of temperature on drying. The drying rate was found to be the lowest in sun drying of 2cm slice with a value of 0.065 g/min. This might be due to the fact that increase in surface area reduces the rate of moisture removal per unit time. The internal resistance to moisture transport is much less than the external resistance to water vapour removal from the product surface (Balakrishnan, 2001) [1]. Hence, the drying rate was lower in 2cm slices when compared to the samples with slice thickness of 0.5 and 1.0 cm. The earlier findings of Nema (2004) [12]. in carrot, Hansen *et al*., (1999) [7]. in taxus and Pawer *et al*., (1988) [14]. in onion substantiate the present results.

C. Alkaloid content

Medicinal plants, in general, warrants cautious drying methods at optimum temperatures as a precaution to minimize the loss of heat sensitive constituents as reported by Tesic *et al.,* (1998) [23]. The alkaloid content viz., gymnemic acid was significantly influenced by different methods of drying. The highest content (344.25 mg $100g^{-1}$) was recorded in shade drying (Table 2). To fetch higher price and improve the quality of the produce, the dried leaves should possess certain desirable traits such as high recovery percent, retention of green color and high alkaloid content. The present findings is in consonance with the results obtained by Yuvaraj (2006) in Wedelia with highest phenolics, tannin and wedelolactone contents in the shade dried sample under ambient temperature. In another experiment with senna, shade drying was the best in retaining the leaf colour with maximum sennoside content as compared to mechanical drying methods (Subha Vasugi, 2006).

In *Plectranthus forskholii*, the alkaloid content viz., forskolin was significantly influenced by different methods of drying. The product with high forskolin content was considered to be the best as it depends on the drying temperature, slice thickness and proper storage condition. The highest content (0.68%) was recorded in mechanical drying of 0.5 cm slice thickness at 40 °C as compared drying at temperatures 50 ^{O}C and 60 °C respectively (Table 5). This might be due to thermal degradation of stored compounds resulting in lower recovery of biochemical constituents. The results are substantiated with the observations made by Sablani *et al*., (2003) [21]. in potato and Rajnish Banga and Bawa (2002) [18]. in carrot and Rajangam (2006) [17]. in medicinal coleus.

1. Standardization of storage containers

Proper packaging and storage play a vital role in deciding the keeping quality of any raw material. Even it is well dried, improper package and storage may pave way to moisture ingress, which in turn catalyze spoilage and quality deterioration. The results of storage studies revealed that irrespective of the crop under study, the dried sample packed in polyethylene lined gunny bag (T2) retained the alkaloid upto 4 months with 438.10 mg $100g^{-1}$ of gymnemic acid and 0.52% forskolin contents respectively while rapid deterioration was recorded the storage under ambient conditions (Table 6). This is in accordance with the results of Joy *et al.,* (2003) [8] in kaempferia and Rajangam (2005) [16] in coleus. Polythene lined gunny bags would have helped to retain the chemical constituents better than other treatments by preventing microbial contamination. This is in agreement with the findings of Elsohly *et al.,* (1994) [4] in Taxus and Pruthi (2001) [15] in sage, who observed that dried materials stored at room temperature in air tight closed package retained the quality without much change in chemical constituents.

From the above experiment, it could be concluded that method of drying and storage decides upon the ultimate appearance, marketability and extended retention of alkaloids of medicinal plants. Gymnema can be dried under shade without thermal degradation, retaining the green colour of the leaves. Likewise mechanical drying of medicinal coleus under 40 ^{O}C was optimal for attaining the appropriate moisture and preservation of forskolin content. Polythene lined gunny bags can be used for storage of medicinal plants with extended shelf life in terms of retention of alkaloids and prevention of microbial contamination.

Table 1: Effect of different drying methods on drying time and drying rate of *Gymnema sylvestre*

Drying Time (hrs)	Fully under sun drying		Shade drying		Sun drying followed by shade drying		Shade drying followed by sun drying	
	Weight (g)	Drying rate (g/min)	Weight (g)	Drying rate (g/min)	Weight (g)	Drying rate (g/min)	Weight (g)	Drying rate (g/min)
0	100.00	0	100.00	0	300.00	0	300.00	0
1	80.50	0.67	92.40	0.43	259.90	0.66	262.90	0.66
2	71.50	0.63	87.60	0.41	221.60	0.63	245.60	0.63
3	64.70	0.56	84.30	0.40	188.20	0.55	210.20	0.55
4	55.20	0.51	81.50	0.38	157.30	0.51	192.30	0.51
5	50.40	0.48	80.90	0.37	127.30	0.50	154.30	0.50
6	43.70	0.41	78.40	0.35	102.80	0.40	132.80	0.40
7	38.90	0.34	76.20	0.33	82.30	0.34	100.73	0.34
8	32.50	0.16	75.20	0.32	79.20	0.05	85.20	0.25
9	29.80	0.13	73.10	0.30	76.20	0.05	80.20	0.25
10	27.40	0.11	70.80	0.29	73.40	0.05	78.40	0.20
11	26.50	0.10	68.50	0.27	70.70	0.05	75.70	0.15
12	25.10	0.03	65.20	0.25	68.00	0.04	72.00	0.14
13	24.35	0.01	61.80	0.23	65.50	0.04	68.50	0.10
14	24.30	0.00	59.60	0.22	63.00	0.04	65.00	0.10
15			56.80	0.21	60.50	0.04	60.50	0.08
16			54.70	0.20	58.30	0.04	58.30	0.05
17			51.80	0.20	56.20	0.04	54.20	0.02
18			50.20	0.18	54.10	0.04	48.10	0.02
19			48.50	0.17	52.00	0.03	32.00	0.01
20			46.90	0.15	50.00	0.03	27.48	0.00
21			44.40	0.12	48.20	0.03		
22			42.80	0.10	46.70	0.03		
23			39.70	0.08	45.70	0.03		
24			35.80	0.06	45.70	0.02		
25			32.40	0.06	32.40	0.02		
26			29.00	0.05	30.10	0.02		
27			27.80	0.04	28.56	0.01		
28			27.00	0.03	26.40	0.00		
29			26.40	0.02				
30			25.90	0.02				
31			25.40	0.01				
32			25.40	0.00				

Table 2. Effect of drying methods on gymnemic acid content of Gymnema *sylvestre*

Drying method	Duration of drying (hrs)	Drying rate (g/min)	Gymnemic acid (mg $100g^{-1}DW$)
Sun drying	14	0.276	310.46
Shade drying	32	0.148	344.25
Sun drying followed shade drying	28	0.236	307.95
Shade drying followed sun drying	20	0.189	312.40
SE (d)	0.865	0.002	1.414
CD (at 5 %)	1.752	0.004	2.589

Table 3: Effect of sun drying on drying time and drying rate of *Plectranthus forskohlii*

Drying Time (hrs)	Slice thickness of 0.5cm		Slice thickness of 1cm		Slice thickness of 2 cm	
	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}
0	100.00	0.000	100.00	0.000	100.00	0.000
2	80.00	0.167	85.00	0.125	86.00	0.117
4	67.00	0.138	73.00	0.113	74.00	0.108
6	56.00	0.122	65.00	0.100	64.50	0.097
8	48.50	0.107	58.00	0.094	56.50	0.091
10	41.00	0.100	52.00	0.088	50.00	0.083
12	36.00	0.092	47.50	0.082	44.00	0.078
14	31.00	0.082	43.50	0.079	39.00	0.073
16	26.00	0.071	39.50	0.072	35.00	0.068
18	23.00	0.037	36.00	0.069	32.00	0.063
20			32.50	0.063	29.50	0.059
22			29.50	0.059	27.50	0.054
24			27.00	0.047	26.00	0.051
27			25.00	0.035	24.80	0.046
30					23.80	0.042
33					22.80	0.039
36					22.00	0.036

Table 4: Effect of mechanical drying on drying time and drying rate of *Plectranthus forskohlii*

Drying Time (min)	Slice thickness of 0.5cm						Slice thickness of 1cm						Slice thickness of 2 cm					
	40 ^{O}C		50 ^{O}C		60 ^{O}C		40 ^{O}C		50 ^{O}C		60 ^{O}C		40 ^{O}C		50 ^{O}C		60 ^{O}C	
	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}	Weight (g)	Drying rate g min^{-1}
0	100.00	0.000	100.00	0.000	100.00	0.000	100.00	0.000	100.00	0.000	100.00	0.000	100.00	0.000	100.00	0.000	100.00	0.000
30	88.00	0.400	84.00	0.533	79.50	0.683	89.00	0.367	87.00	0.433	82.00	0.600	89.50	0.350	87.50	0.417	88.00	0.400
60	78.00	0.366	72.00	0.467	63.00	0.617	78.50	0.358	76.00	0.400	67.50	0.542	79.00	0.350	76.00	0.400	77.50	0.375
90	67.50	0.361	60.00	0.444	50.00	0.556	70.00	0.333	65.50	0.383	54.50	0.506	70.00	0.332	65.50	0.383	69.00	0.354
120	58.50	0.345	50.00	0.417	39.50	0.504	61.00	0.325	56.00	0.367	44.00	0.467	62.50	0.313	57.50	0.354	60.50	0.329
150	50.50	0.330	42.00	0.367	32.50	0.450	53.50	0.310	46.50	0.357	35.50	0.420	55.00	0.300	51.50	0.336	53.00	0.303
180	43.00	0.316	35.50	0.358	29.00	0.394	46.00	0.300	39.50	0.336	30.50	0.386	50.00	0.278	46.50	0.318	46.50	0.276
210	36.00	0.304	31.00	0.329	27.50	0.345	40.00	0.286	35.50	0.307	28.50	0.340	44.50	0.264	41.50	0.294	41.00	0.258
240	31.00	0.287	28.50	0.298	26.70	0.305	35.00	0.271	31.50	0.285	27.00	0.304	40.50	0.248	37.00	0.271	35.00	0.240
270	27.00	0.270	27.00	0.270	25.90	0.274	31.00	0.256	28.50	0.265	26.10	0.274	36.50	0.235	32.00	0.252	31.00	0.222
300	24.60	0.251	26.00	0.247	25.50	0.238	28.00	0.240	27.00	0.243	25.50	0.248	33.50	0.212	29.50	0.235	27.50	0.206
330	23.60	0.231	25.20	0.226	25.20	0.217	26.30	0.223	26.20	0.224	25.10	0.227	31.00	0.209	27.50	0.220	25.50	0.184
360	22.80	0.214	24.70	0.209	24.90	0.200	24.70	0.209	25.60	0.207	24.80	0.209	29.00	0.197	26.30	0.205	25.00	0.173
390	22.20	0.199	24.40	0.194			24.00	0.195	25.20	0.192	24.60	0.193	27.50	0.186	25.50	0.191	24.50	0.155
420	22.00	0.185					23.60	0.182	24.90	0.179	24.30	0.180	26.00	0.176	24.50	0.180	23.50	0.137
450	21.90	0.173					23.40	0.170	24.70	0.167			25.00	0.167	23.80	0.169	22.80	0.150
450							23.20	0.160	24.60	0.157			24.20	0.158	23.10	0.160	22.40	0.135
480							23.10	0.151					23.70	0.150	22.60	0.152		
510													23.40	0.142	22.30	0.144		
540													23.10	0.135	22.00	0.137		
570													23.10	0.129				

Table 5: Drying characteristics on forskolin content in *Plectranthus forskohlii*

Drying method	Duration of drying	Drying rate (g/min)	Forskolin (%)
Sun drying of 0.5 cm slice thickness	18 hrs	0.092	0.48
Sun drying of 1 cm slice thickness	27 hrs	0.073	0.45
Sun drying of 2 cm slice thickness	36 hrs	0.065	0.42
Mechanical drying of 0.5 cm slice thickness at 40°C	450 min	0.265	0.68
Mechanical drying of 0.5 cm slice thickness at 50°C	390 min	0.311	0.62
Mechanical drying of 0.5 cm slice thickness at 60°C	360 min	0.370	0.58
Mechanical drying of 1.0 cm slice thickness at 40°C	510 min	0.241	0.65
Mechanical drying of 1.0 cm slice thickness at 50°C	480 min	0.265	0.64
Mechanical drying of 1.0 cm slice thickness at 60°C	420 min	0.326	0.56
Mechanical drying of 2.0 cm slice thickness at 40°C	600 min	0.216	0.60
Mechanical drying of 2.0 cm slice thickness at 50°C	570 min	0.241	0.59
Mechanical drying of 2.0 cm slice thickness at 60°C	480 min	0.229	0.52

Table 6: Effect of storage methods on alkaloid content of gymnema and medicinal coleus

Treatments	Gymnemic acid (mg 100g^{-1} dry weight)					Forskolin (%)				
	Months after storage					Months after storage				
	0	1	2	3	4	0	1	2	3	4
T_1- Jute Gunny bags	442.20	441.10	440.62	435.38	434.12	0.70	0.70	0.65	0.50	0.42
T_2- Polythene lined Gunny bags	442.20	442.20	441.80	439.00	438.10	0.70	0.70	0.65	0.60	0.52
T_3- Ventilated polythene lined Gunny bags	442.20	442.20	440.85	438.70	437.45	0.70	0.70	0.62	0.58	0.48
T_4- Storage at ambient condition	442.20	440.00	435.25	429.10	424.58	0.70	0.68	0.54	0.45	0.38

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