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Influence of drying methods on nutritional composition of Chekurmanis (*Sauropus androgynus* L.)

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Abstract
Micronutrient and vitamin deficiencies has spread all over the world. In most countries, especially women and children are malnourished due to lack of consumption of vegetables. Though green leafy vegetables (GLVs) are rich in vitamins and micronutrients, remains underutilised for human consumption. GLVs are highly perishable due to their high water content, it is important to process the greens to add value and promote their consumption in our regular diet. Chekurmanis is one such green leafy vegetable that is highly nutritious but is still underutilised. The purpose of this study is to compare the nutritional value of Chekurmanis leaves collected at three different leaf positions *viz.*, top, middle and bottom whorl leaves and processed by different methods of drying (sun, shade and solar drying). The biochemical analysis revealed a considerable increase in all nutrients in dried leaf samples, indicating that they are concentrated source of nutrients. Shade dried samples had the maximum nutrient retention, followed by solar and sun dried samples. With respect to leaf positions, bottom whorl leaves holds the maximum nutritive value compared to top and middle whorl leaves.

Keywords: *Sauropus androgynus*, leaf positions, drying methods, nutrient analysis

1. Introduction

COVID-19 pandemic has made the whole world be conscious of health care. The pandemic threw lot challenges to human race, from overcoming global malnutrition to understand the importance of sustainable healthy eating to combat malnutrition / hidden hunger and diet related non–communicable diseases. Chekurmanis (*Sauropus androgynus* L.) is one such crop which is highly nutritious, shrubby, multivitamin green belonging to the family Phyllanthaceae that grows profusely in Indonesia, Malaysia and Singapore (South and Southeast Asia), but is neglected in India, with the exception of some portions of Southern India. Besides its nutritive value and health benefits, Chekurmanis leaves contain the alkaloid papaverine (580 mg/100g of fresh leaves). It was reported that 200 mg of papaverine acts as antispasmodic drug and its excessive consumption in raw form (fresh leaves) would cause drowsiness and respiratory disorders (Kalpana *et al*., 2017) [20]. In the processed form, ill effect of the alkaloid in the leaves gets reduced and fits in our daily diet. Drying extends the shelf life of produce, reduces its volume and makes it easier to store and handle. The influence of several drying processes (shade, sun and solar drying) on the nutritional value of Chekurmanis leaves were explored in this study.

2. Materials and Methods

2.1 Procurement of raw material

Fresh leaves of Chekurmanis were collected from Field No.26 of Western Block Farm located at Department of Vegetable Science, Horticultural College and Research Institute, TNAU, Periyakulam, Theni district.

2.2 Stripping of leaflets

After harvesting the fresh Chekurmanis leaves from the plants, the leaflets were stripped off from the petiole and then the discoloured and deformed leaves if any were discarded.

2.3 Washing

Freshly collected Chekurmanis leaves were washed in water to eliminate dust and dirt from the leaves. After washing, the leaves were spread on a blotting paper to dry the water present on the leaves.

2.4 Drying of Chekurmanis leaves

Fresh Chekurmanis leaves were dried using three different methods *viz*., sun drying, shade drying (room temperature) and solar drying. The initial moisture content of fresh Chekurmanis leaves was estimated by using hot air oven at 105 °C for 24 hours (AOAC, 2000) [1].

2.4.1 Sun Drying

A known quantity (2.0 kg) of fresh Chekurmanis leaves were laid out as a single layer on an aluminium tray and spread in such a manner that they received the maximum sunlight during the day. The weight loss was recorded every one hour during the drying process using a precision weighing scale. The drying process was continued until no weight loss was noted.

2.4.2 Shade Drying

Fresh Chekurmanis leaves of known quantity (2.0 kg) were spread as a single layer on an aluminium tray (100 mm × 40 mm) placed inside a room and dried at room temperature. During shade drying, the ambient room temperature ranged from 27 to 30 ºC, with relative humidity ranging from 50 to 60%. The drying of Chekurmanis leaves continued until the weight remained consistent.

2.4.3 Solar tunnel drying

The solar power was used to manage the temperature controlling system in the solar tunnel dryer. The trays were loaded with 1.0 kg of Chekurmanis leaves per tray in this drier, which were kept at a temperature of 40-42°C for uniform drying. The leaves that showed crispiness after 6 hours of drying were used to prepare Chekurmanis dry leaf powder (Emelike *et al*., 2020) [10].

2.5 Biochemical analysis

The ascorbic acid content analysis was done by titrimetric method using 2, 6-dichlorophenol indophenol dye (Ranganna, 2000) [35]. Total phenols was estimated by Folin- Ciocalteau method (Singleton *et al*., 1999) [40] and total chlorophyll was estimated spectrophotometrically by Arnon (1945) [5] method. All minerals (Iron, Zinc, Manganese and Calcium) were analysed using AOAC (2000) [1] method and vitamin A content was analysed using Jackson *et al.* (1973) method and Vitamin E by Rosenberg (1972) [36] method.

2.6 Statistical analysis

The Completely Randomized Design (CRD) was employed to statistically analyse the results and observations recorded during the experiment were analysed at 5% level of significance using AGRESS software to evaluate the different drying methods carried out during the study.

3. Result and Discussion

3.1 Moisture

The moisture content was reduced as a result of the drying process. The moisture content decreased as the drying temperature and time increased. Moisture content provides a favourable environment for microbe growth; consequently, it must be reduced if to be stored for long period of time (Ladan *et al*., 1997) [25]. Moisture content observed in shade dried Chekurmanis leaves was 6.7%, followed by sun (6.2%) and solar (5.9%) drying.

3.2 Chlorophyll

The chlorophyll pigments found in plant materials are primarily responsible for the colour of green leafy vegetables. Colour degradation in dried materials is caused by a variety of factors, including drying temperature and relative humidity. It is believed that chlorophyll is heat sensitive and its retention is affected by temperature and duration of heat treatment. (Shahabi *et al*., 2014) [39].

Table 1: Proximate composition of Chekurmanis at different leaf positions under different drying methods

Drying method	Whorl leaves	Chlorophyll (mg/100g)	Protein (g/100g)	Carbohydrate (g/100g)	Vitamin A (mg/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)
Solar drying	Top	2.12 ± 0.03	14.23 ± 0.27	25.78 ± 0.27	21.9 ± 0.32	16.43 ± 0.02	3.98 ± 0.03
	Middle	3.26 ± 0.01	16.18 ± 0.26	28.91 ± 0.26	24.6 ± 0.34	17.46 ± 0.16	4.67 ± 0.03
	Bottom	4.12 ± 0.02	17.89 ± 0.19	30.17 ± 0.28	26.1 ± 0.24	18.78 ± 0.25	5.32 ± 0.01
Sun drying	Top	1.67 ± 0.01	16.80s ± 0.15	23.07 ± 0.23	16.53 ± 0.23	9.67 ± 0.34	1.34 ± 0.02
	Middle	2.79 ± 0.02	21.00 ± 0.63	26.19 ± 0.36	17.89 ± 0.32	11.14 ± 0.05	2.01 ± 0.04
	Bottom	3.85 ± 0.28	19.48 ± 0.15	27.63 ± 1.04	18.54 ± 0.38	12.98 ± 0.06	3.23 ± 0.02
Shade drying	Top	2.87 ± 0.32	20.99 ± 0.25	18.9 ± 0.34	23.75 ± 0.22	22.76 ± 0.14	3.47 ± 0.05
	Middle	3.99 ± 0.31	21.99 ± 0.30	19.23 ± 0.25	25.04 ± 0.23	24.85 ± 0.19	3.64 ± 0.01
	Bottom	4.83 ± 0.42	23.47 ± 0.16	20.65 ± 0.35	28.54 ± 0.43	28.92 ± 0.14	3.17 ± 0.02
SE (d)		0.319	0.426	0.634	0.441	0.256	0.040
CD (0.05)		0.649	0.868	1.291	0.897	0.521	0.082

The results presented in Table 1 depict that shade dried bottom whorl leaves retained the maximum amount of chlorophyll (4.83 mg/100g) when compared to middle and top whorl leaves, followed by solar drying (4.12 mg/100g) and sun drying (3.85 mg/100g). This is due to the fact that thermal dehydration demonstrated stronger deterioration effects than non-thermal drying (Kumar *et al*., 2014) [24].

3.3 Protein

The protein content of shade dried Chekurmanis leaves was 23.47 g, sun dried (20.99 g) and solar dried (19.48 g). The highest protein content was found in shade dried leaves, whereas the lowest was found in solar dried leaves (Table 1). The basal whorl leaves had the highest protein content which was significantly higher than the other two leaf positions *viz*., top and middle whorl leaves in all the three drying methods employed. The decrease in protein content could be due to tannins in younger leaves, which form numerous compounds with the protein and so limits their availability (Cho *et al*., 2001) [7]. Protein content in leaves was shown to be considerably reduced after drying, owing to protein denaturation at high temperatures (Zalpouri *et al*., 2021). Kakade and Hathan (2014) [43, 19] discovered a similar tendency with beetroot leaf powder. The considerable loss of macronutrients during drying may be due to the stability of the bonds involved.

3.4 Carbohydrate
Carbohydrates aid in fat metabolism and serve as an energy source for humans (Gordon, 2002). Carbohydrate concentration was higher in solar dried (30.17 mg/100g) leaves than sun dried (27.63 mg/100g) and shade dried (20.65 mg/100g) leaves making solar dried sample a better source of energy (Table 1). The value obtained for bottom whorl leaves in sun, solar and shade drying were statistically higher than those obtained for middle and top whorl leaves. The main chemical transformations that occur during drying were changes in their carbohydrate levels (Perera, 2005) [33].

3.5 Vitamin A (β-carotene)
β-carotene is commonly referred as provitamin A since its single molecule is transformed into two molecules of vitamin A after human ingestion (Mertz, 1967). Figure 1 depicts the effect of drying methods on vitamin A (β-carotene) content of Chekurmanis leaves. β-carotene content in sun, shade and solar dried leaves were 18.54, 28.54 and 26.10 mg/100g respectively. After drying, shade drying yielded the highest β-carotene content (28.54 mg/100g) in Chekurmanis and sun drying yielded the lowest (18.54 mg/100g). Also, the bottom whorl leaves recorded the maximum amount of β-carotene (28.54 mg/100g) when compared with top and middle whorl leaves in the drying methods employed. Devadas *et al*. (1978) discovered that sun dried green leafy vegetables when stored for one year resulted in 10-60% preservation of β-carotene.

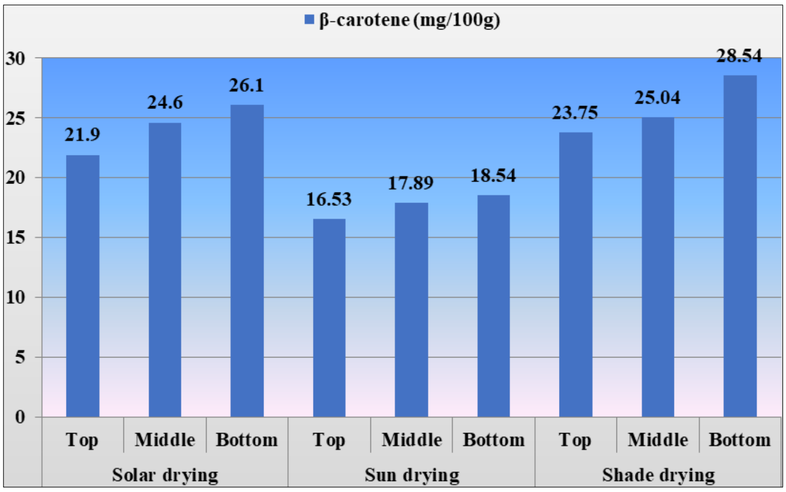

Fig 1: Effect of drying methods on Vitamin A content of Chekurmanis leaves

3.6 Vitamin C (Ascorbic acid)
The amount of vitamin C lost during the drying process is determined by the physical qualities of the product and the method of drying used (Goula and Adampoulous, 2010) [13]. Figure 2 depicts the effect of drying methods on Vitamin C content of Chekurmanis leaves. In the present study, Vitamin C content was found significantly higher (28.92 mg/100g) in the shade dried Chekurmanis leaves compared to solar dried (18.78 mg/100g) and sun dried (12.98 mg /100g). Lee and Kadar (2000) [26] reported that maturity of leaves is a major factor in determining the nutritional value of vegetables. Vitamin C content of plants varies with maturity of leaves, as bottom whorl leaves contained higher amount of Vitamin C when compared with middle and top whorl leaves in all the three methods of drying *viz*., sun, shade and solar drying. This is in accordance with the report of Korus (2010) [23]. High temperatures and long drying period cause vitamin C to oxidise and disintegrate (Vega-Galveza *et al*., 2009; Jin *et al*., 2014) [42, 18]. All drying methods result in significant loss of vitamin C (Kiremire *et al*., 2010) [21, 22], which could be attributable to the fact that vitamin C is particularly susceptible to oxidative degradation in the presence of heat, light, oxygen, enzymes, moisture, and metal ions (Russell and MacDowell, 1989) [37].

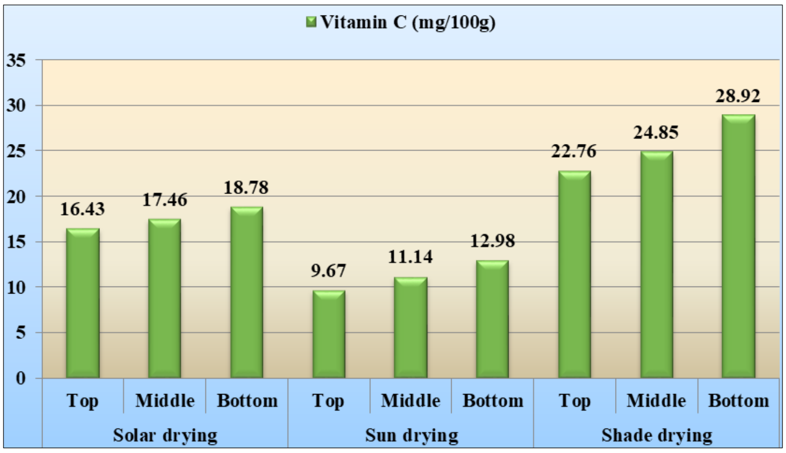

Fig 2: Effect of drying methods on Vitamin C content of Chekurmanis leaves

3.7 Vitamin E (α - Tocopherol)

Among the three different methods of drying *viz*., shade, sun and solar drying, Vitamin E content was found the maximum under solar drying (5.32 mg/100g), followed by sun (3.23 mg/100g) and shade drying (3.17 mg/100g). Figure 3 depicts the effect of drying methods on Vitamin E content of Chekurmanis leaves. It has been found that Vitamin E content varies with the maturity of leaves as bottom whorl leaves recorded the highest Vitamin E content than top and middle whorl leaves. Some publications have observed that tocopherols (Vitamin E) are relatively heat stable; however, temperature changes may modify the mode of action of some antioxidants, and thus the order of their effectiveness (Maestri *et al*., 2006). Furthermore, depending on the food matrix, heat treatment degradation could release a large amount of vitamin E related to protein or phospholipids.

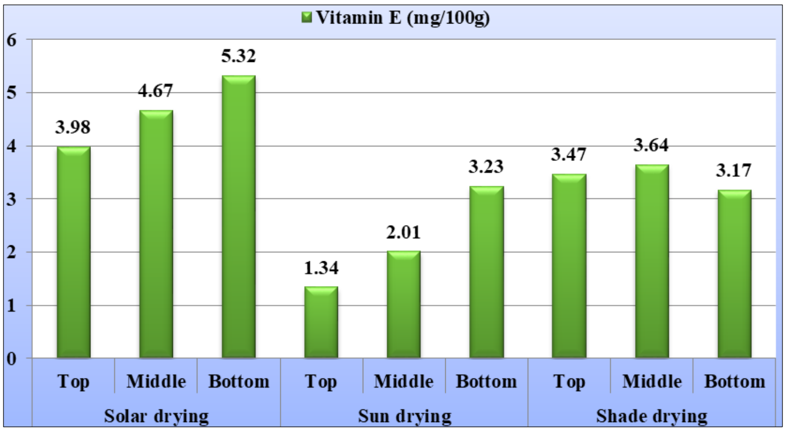

Fig 3: Effect of drying methods on Vitamin E content of Chekurmanis leaves

3.8 Phenol

Phenolic complexes serve an important role in cells and have the potential to be antioxidants (Kim *et al*., 2017). The drying procedure increased the phenol content and thus the antioxidant capacity. The phenolic content in shade, sun and solar dried leaf samples were 70.76, 69.85 and 62.34 mg/100g respectively (Table 2). The phenolic content was recorded to be the highest (70.76 mg/100g) in shade dried leaves and the lowest (62.34 mg/100g) in solar dried leaves. Phenolic compounds are temperature sensitive and if the cellular structure is disrupted during the drying process, there is significant loss in its content (Jaworska *et al*., 2014) [17]. The loss of phenolic complexes during the thermal drying process is caused by the mechanism of activation enzymes (polyphenoloxidase and peroxidase). Furthermore, processes such as changes in chemical structure and binding of phenols to protein are responsible for the loss of phenolic content (Gumusay *et al*., 2015). According to the findings, maturity influences the concentration of total phenols (Kumar *et al*., 2022). Based on the maturity of leaves, in this study also the bottom whorl leaves possessed the maximum phenol content in comparison with top and middle whorl leaves.

Table 2: Proximate composition of Chekurmanis at different leaf positions under different drying methods

Drying method	Whorl leaves	Phenol (mg/100g)	Calcium (mg/100g)	Potassium (mg/100g)	Iron (mg/100g)	Manganese (mg/100g)	Zinc (mg/100g)
Solar drying	Top	55.67 ± 0.36	974.61 ± 1.27	223.50 ± 0.66	26.87 ± 0.60	92.48 ± 0.73	4.87 ± 0.24
	Middle	58.90 ± 0.45	1211.01 ± 0.73	231.90 ± 0.75	28.54 ± 0.68	102.34 ± 0.72	5.41 ± 0.01
	Bottom	62.34 ± 0.28	1964.94 ± 0.68	244.50 ± 0.80	30.65 ± 0.98	106.89 ± 0.94	6.42 ± 0.01
Sun drying	Top	61.68 ± 0.33	789.65 ± 1.07	212.03 ± 0.96	22.87 ± 0.73	87.23 ± 0.53	2.16 ± 0.01
	Middle	65.52 ± 0.25	982.09 ± 1.63	225.65 ± 0.76	24.56 ± 0.87	91.45 ± 1.22	4.12 ± 0.01
	Bottom	69.85 ± 0.39	1543.78 ± 2.10	231.56 ± 1.42	27.05 ± 0.51	103.56 ± 0.78	5.56 ± 0.01
Shade drying	Top	63.78 ± 0.09	1123.09 ± 2.06	239.54 ± 0.81	29.87 ± 0.72	95.62 ± 0.70	6.12 ± 0.01
	Middle	67.94 ± 0.42	1698.34 ± 1.89	245.23 ± 0.73	33.76 ± 0.80	105.34 ± 0.74	7.49 ± 0.02
	Bottom	70.76 ± 0.26	2376.45 ± 2.69	256.34 ± 0.76	37.54 ± 0.44	110.62 ± 0.94	8.99 ± 0.19
SE (d)		0.474	2.402	1.245	1.027	1.183	0.118
Cd (0.05)		0.965	4.892	2.535	2.091	2.409	0.241

3.9 Calcium

Calcium is essential for the neurological system, cell signalling and muscular contraction. It also aids in the maintenance of healthy teeth and bones. According to Sadler (2011), calcium is used by cells for ion transfer and causes the production of many enzymes in the human body. In the present study, calcium content was reported the maximum in shade dried (2376.45 mg/100g) leaves, followed by solar (1964.94 mg/100g) and sun dried (1543.78 mg/100g) leaves (Table 2). The calcium content of bottom whorl leaves was substantially higher than that of other two leaf positions (top and middle whorl leaves). Amanabo *et al*. (2012) [4] observed that basal leaves had the highest calcium content. This could be due to the fact that calcium is immobile (non-trans locatable) within plants and accumulates in older tissues throughout the growth season. Hence, Ca deficiency symptoms develop first in the plant's young growing section (Fageria *et al*., 2009) [11].

3.10 Potassium

The high potassium levels in the dried samples may be advantageous for usage as a therapeutic and are essential for bone (Dzomeku *et al*., 2006) [9]. In the present study, potassium content was observed the maximum in shade drying (256.34 mg/100g), followed by solar (244.5 mg/100g) and sun (231.56 mg/100g) drying (Table 2). Sun dried greens had much lower potassium levels. This observation is most likely due to potassium being a cationic element does not polarise easily when heated, yet oxides when exposed to light and air. When the plant approach maturity, the nutrient content (potassium) gets increased *(i.e.)* bottom whorl leaves contained more potassium content when compared to top and middle whorl leaves. This result is consistent with the results published by Platel and Srinivasan (2017) [34] and a similar trend with plant age was noted by Adedrian *et al*. (2015) in the tender and mature leaf stages of the *Celosia argentata* plant.

3.11 Micronutrients
In the current investigation, concentrated amounts of micronutrients (Fe, Zn, Mn) with multifold increase were found in dry form. The miconutrient content of the Chekurmanis leaves under different drying methods are presented in Table 2. When compared to other drying methods, shade dried Chekurmanis leaves had higher Iron, Zinc and Manganese content (37.54, 8.99 and 110.62 mg/100g respectively) in the bottom whorl leaves, whereas solar (30.65, 6.42, 106.89 mg/100g) and sun (27.05, 5.56, 103.56 mg/100g) dried leaves had comparatively lower content. Hassan *et al*. (2007) discovered that drying increased mineral elements except sodium. In tomatoes and *Vernonia amygdalina* (bitter leaf), solar drying retained more minerals than sun drying (Aliero and Abdullahi, 2009). Drying treatment has a beneficial effect on maintaining the mineral content of vegetables and hence remains the best approach for maximising the mineral content of consumed vegetables when compared to fresh. There was no significant variation in micronutrient (Fe, Zn, Mn) content obtained between different leaf positions (top, middle and bottom whorl leaves). This could be due to the mineral's rapid mobility and availability in all parts of the plant. (Taiz *et al*., 2002).

4. Conclusion
From the above results of the study, it can be concluded that shade drying method was the best method of drying of Chekurmanis leaves. There was better retention of nutrients, vitamins and micronutrients in shade drying as compared to sun and solar drying. Likewise, bottom whorl leaves retained the maximum amount of nutrition than top and middle whorl leaves. If India focuses on consumption of these nutrient rich green leaves, deficiency syndromes from our society can be eliminated, making Healthy India in a short reach. Consumption of this green leafy vegetable should be encouraged, particularly among vulnerable groups. This may be a viable strategy for combating micronutrient malnutrition / hidden hunger in our country.

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