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Effect of moisture levels on various phytoconstituents of turmeric (*Curcuma longa* L.)

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Abstract
Moisture ingress produce changes in texture, colour, flavor, nutritional value and quality of food items. The present study was undertaken to study the effect of moisture levels viz. 5% moisture level (more than normal), 10% moisture level (more than normal) and normal moisture level (control) on phytoconstituents of turmeric rhizomes. Contents of total phenols, flavonoids, curcumin and sugars decreased under the influence of moisture during storage. The decrease was more at 10% moisture level in comparison to 5% moisture level. The contents of total phenols in turmeric rhizomes (var. BSR-2 and germplasm material) samples with 10%, 5% and normal moisture level after 64 days of storage were respectively 21.05, 21.27, 24.88 and 18.00, 18.17, 22.68 mg GAE/g, flavonoids (59.22, 64.61, 87.27 and 43.79, 47.70, 65.50 mg CE/g), curcumin (4.432, 4.436, 4.476 and 3.533, 3.541, 3.607 g/100g), total sugars (23.89, 24.86, 34.19 and 19.79, 21.00, 33.06 mg/g), reducing sugars (6.31, 6.51, 8.93 and 4.89, 5.37, 8.53 mg/g), non-reducing sugars (17.58, 18.35, 25.26 and 14.90, 15.63, 24.53 mg/g).

Keywords: *Curcuma longa*, moisture levels, total phenols, flavonoids, curcumin, sugars

Introduction
Currently there is an increase in the demand for natural antioxidants obtained from edible plants, especially spices and herbs being an excellent source of polyphenolic compounds. Plant polyphenolics include phenolic acids, flavonoids, tannins, tocopherols, stilbenes, lignans, tocotrienols and hydroxycinnamic acid derivatives. Spices like turmeric (*Curcuma longa* L.) is a rich source of plant polyphenolics. The plant is a perennial herb belonging to family Zingiberaceae and turmeric rhizomes contains carbohydrates (69.4%), protein (6.3%), fat (5.1%), minerals (3.5%), curcumin (2-5%), sugar (3%) and moisture (13.1%) [1]. Curcumin (diferuoyl methane) which is the most active component of turmeric is responsible for its yellow colour. It has a wide variety of phytochemicals including curcumin, zingiberene, curcumenol, curcumol, tetrahydrocurcumin, triethylcurcumin, turmerin, turmerone and turmeronols [2]. The nature of many phytoconstituents such as phenolics and flavonoids present in spices may be altered due to the presence of moisture. Powdered dehydrated products require protection against ingress of moisture and oxygen [3]. Moisture is of great importance for the safe storage of spices, cereals and their products regarding microorganism, particularly certain species of fungi. Poisonous substances secreted by the fungi render the food unfit for human consumption. Moisture content also affects the growth of mould infecting all stored food items [4]. It is generally accepted that climatic conditions lead to physical changes in stored food items through the movement of moisture, which leads to deterioration. Survey of the literature reveals that no systematic work has been done on the comparative study of various moisture levels on total phenols, flavonoids, curcumin and sugars content of turmeric. Thus, the objective of present study was to observe the effect of moisture levels on phytoconstituents of powdered samples of turmeric rhizomes.

Results and discussion
Total phenols content
Total phenols content (mg GAE/g) in powdered samples of turmeric rhizomes (var. BSR-2) with 5% moisture level (more than normal) was 24.34 after 7 days of storage followed by 23.58, 23.09, 22.36, 21.71 and 21.27 after 14, 21, 28, 35 and 64 days of storage, respectively (Table 1). The corresponding values for samples with 10% moisture level (more than normal) were 24.09, 23.39, 22.73, 22.14, 21.64 and 21.05. Similarly, in powdered samples of turmeric rhizomes (germplasm material) with 5% moisture level (more than normal) total phenols content was 21.83, 21.12, 20.26, 19.49, 19.02 and 18.17 after 7, 14, 21, 28, 35 and 64 days of storage, respectively (Table 1). The corresponding values for samples with 10% moisture level (more than normal) were 21.67, 20.97, 20.06, 19.25, 18.68 and 18.00.

The decrease in total phenols content may be probably due to degradation of phenols into their derivatives under the influence of moisture during storage. The results of present study well matched with the studies on *Capsicum annuum* that total phenols content was dependent on storage conditions and reported that total phenols content in samples of *C. annuum* with moisture content of 4, 7 and 12% showed a highly significant decrease (about 7%) during three months of storage period [5]. Moisture content could affect the extraction ability because of high water content in mushroom samples, which could dilute the concentration of total phenols content in plant tissues resulting in lower contents of total phenols [6].

Flavonoids content

Flavonoids content (mg CE/g) in powdered samples of turmeric rhizomes (var. BSR-2) with 5% moisture level (more than normal) was 86.36 after 7 days of storage followed by 81.05, 76.34, 71.40, 66.91 and 64.61 after 14, 21, 28, 35 and 64 days of storage, respectively (Table 2). The corresponding values for samples with 10% moisture level (more than normal) were 85.24, 80.36, 73.99, 66.76, 61.04 and 59.22. Similarly, in powdered samples of turmeric rhizomes (germplasm material) with 5% moisture level (more than normal) flavonoids content was 64.56, 60.64, 57.01, 52.97, 49.68 and 47.70 after 7, 14, 21, 28, 35 and 64 days of storage, respectively (Table 2). The corresponding values for samples with 10% moisture level (more than normal) were 63.97, 60.05, 55.34, 49.97, 45.59 and 43.79. On comparing the flavonoids data of turmeric rhizomes (var. BSR-2) samples with 5% and 10% moisture level (more than normal) with the data of normal moisture (control), it was found that overall decrease in flavonoids content was 25.97 and 32.14%, respectively and for turmeric rhizomes (germplasm material) was 27.18 and 33.15%, respectively after 64 days of storage. The decrease in flavonoids content may be probably due to degradation of flavonoids into their derivatives under the influence of moisture during storage. Results of present study are in agreement with other studies on different crops. Moisture content could lower the concentration of flavonoid content in plant tissues resulting in lower contents of flavonoids in mushroom samples [6]. Flavonoid content in golden apples decreased during storage under 95% relative humidity for 135 days [7].

Curcumin content

Curcumin content (g/100g) in powdered samples of turmeric rhizomes (var. BSR-2) with 5% moisture level (more than normal) was 4.462 after 7 days of storage followed by 4.452, 4.447, 4.440, 4.439 and 4.436 after 14, 21, 28, 35 and 64 days of storage, respectively (Table 3). The corresponding values for samples with 10% moisture level (more than normal) were 4.458, 4.447, 4.443, 4.437, 4.435 and 4.432. Similarly, in powdered samples of turmeric rhizomes (germplasm material) with 5% moisture level (more than normal) curcumin content was 3.575, 3.568, 3.562, 3.553, 3.545 and 3.541 after 7, 14, 21, 28, 35 and 64 days of storage, respectively (Table 3). The corresponding values for samples with 10% moisture level (more than normal) were 3.573, 3.562, 3.556, 3.550, 3.540 and 3.533. On comparing the curcumin data of turmeric rhizomes (var. BSR-2) samples with 5% and 10% moisture level (more than normal) with the data of normal moisture (control), it was found that overall decrease in curcumin content was 0.89 and 0.98%, respectively and for turmeric rhizomes (germplasm material) was 1.78 and 2.00%, respectively after 64 days of storage. Curcumin content does not affect much under the presence of moisture during storage period of 7 to 64 days may be probably due to non-polar nature of curcumin, hence, it does not involve in any type of bonding to form derivatives in the presence of moisture.

Total sugars, reducing sugars, non-reducing sugars

Total sugars content (mg/g) in powdered samples of turmeric rhizomes (var. BSR-2) with 5% moisture level (more than normal) was 32.12 after 7 days of storage followed by 30.20, 29.01, 27.25, 25.92 and 24.86 after 14, 21, 28, 35 and 64 days of storage, respectively (Table 4). The corresponding values for samples with 10% moisture level (more than normal) were 31.87, 29.90, 27.97, 26.14, 24.70 and 23.89. Similarly, in powdered samples of turmeric rhizomes (germplasm material) with 5% moisture level (more than normal) total sugars content was 30.24, 28.21, 26.15, 24.25, 22.68 and 21.00. The corresponding values for samples with 10% moisture level (more than normal) were 28.62, 27.30, 25.11, 23.07, 21.46 and 19.79. Reducing sugars content (mg/g) in powdered samples of turmeric rhizomes (var. BSR-2) with 5% moisture level (more than normal) was 8.56 after 7 days of storage followed by 8.01, 7.60, 7.15, 6.72 and 6.51 after 14, 21, 28, 35 and 64 days of storage, respectively (Table 5). The corresponding values for samples with 10% moisture level (more than normal) were 8.34, 7.87, 7.32, 6.95, 6.52 and 6.31. Similarly, in powdered samples of turmeric rhizomes (germplasm material) with 5% moisture level (more than normal) reducing sugars content was 7.94, 7.48, 7.12, 6.14, 5.48 and 5.37. The corresponding values for samples with 10% moisture level (more than normal) were 7.56, 7.05, 6.45, 5.60, 5.13 and 4.89. Non-reducing sugars content (mg/g) in powdered samples of turmeric rhizomes (var. BSR-2) with 5% moisture level (more than normal) was 23.56 after 7 days of storage followed by 22.19, 21.41, 20.10, 19.20 after 14, 21, 28, 35 and 64 days of storage, respectively (Table 6). The corresponding values for samples with 10% moisture level (more than normal) were 23.53, 22.03, 20.65, 19.19, 18.18 and 17.58. Similarly, in powdered samples of turmeric rhizomes (germplasm material) with 5% moisture level (more than normal) non-reducing sugars content was 22.30, 20.73, 19.03, 18.11, 17.20 and 15.63. The corresponding values for samples with 10% moisture level (more than normal) were 21.06, 20.25, 18.66, 17.47, 16.33 and 14.90 mg/g. The decrease in contents of total sugars, reducing sugars and non-reducing sugars in powdered samples of turmeric rhizomes (var. BSR-2) with respect to samples having normal moisture level (control) was 27.29, 27.10 and 27.36%, respectively at 5% moisture level (more than normal) in comparison to 30.13, 29.34 and 30.40%, respectively at 10% moisture level (more than normal) after 64 days of storage period. Similarly, decrease in contents of total sugars, reducing sugars and non-reducing sugars in powdered samples of turmeric rhizomes (germplasm material) with respect to samples having normal moisture level (control) was 36.48, 37.05 and 36.28%, respectively at 5% moisture level (more than normal) in comparison to 40.14, 42.67 and 39.26%, respectively at 10% moisture level (more than normal) after 64 days of storage period. A study on liberica coffee beans showed that sucrose content decreased during storage under relative humidity (66.13 to 74.11%) and the decrease in sucrose content increases with the increase in relative humidity during storage [8]. Total sugars decreased in strawberry samples stored under 85% relative humidity and 5 °C temperature with the advent of storage period [9]. Total sugars content decreased in

samples of herbal drugs with 4.56 to 6.50% moisture and the samples with maximum moisture had minimum amount of total sugars content [10].

Table 1: Total phenols (mg GAE/g) in turmeric rhizomes at different moisture levels

Spices and part	Days	Normal moisture level (Control, T_3)	5% Moisture Level (T_1) (more than normal)		10% Moisture Level (T_2) (more than normal)	
			Total Phenols (mg GAE/g)	Degradation (%)	Total Phenols (mg GAE/g)	Degradation (%)
Turmeric rhizomes (var. BSR-2)	7	24.86±0.02	24.34±0.06	2.09	24.09±0.04	3.10
	14	24.84±0.03	23.58±0.03	5.07	23.39±0.07	5.84
	21	24.90±0.01	23.09±0.05	7.27	22.73±0.03	8.71
	28	24.94±0.02	22.36±0.04	10.34	22.14±0.06	11.23
	35	24.91±0.03	21.71±0.05	12.85	21.64±0.05	13.13
	64	24.88±0.01	21.27±0.08	14.51	21.05±0.08	15.39
Turmeric rhizomes (germplasm material)	7	22.63±0.01	21.83±0.03	3.54	21.67±0.10	4.24
	14	22.71±0.03	21.12±0.04	7.00	20.97±0.05	7.66
	21	22.69±0.03	20.26±0.06	10.71	20.06±0.03	11.59
	28	22.65±0.02	19.49±0.03	13.95	19.25±0.04	15.01
	35	22.70±0.03	19.02±0.05	16.21	18.68±0.07	17.71
	64	22.68±0.02	18.17±0.07	19.89	18.00±0.04	20.63

Table 2: Flavonoids (mg CE/g) in turmeric rhizomes at different moisture levels

Spices and part	Days	Normal moisture level (Control, T_3)	5% Moisture Level (T_1) (more than normal)		10% Moisture Level (T_2) (more than normal)	
			Flavonoids (mg CE/g)	Degradation (%)	Flavonoids (mg CE/g)	Degradation (%)
Turmeric rhizomes (var. BSR-2)	7	87.25±0.02	86.36±0.07	1.02	85.24±0.08	2.30
	14	87.29±0.03	81.05±0.14	7.15	80.36±0.09	7.92
	21	87.24±0.04	76.34±0.06	12.49	73.99±0.06	15.19
	28	87.26±0.08	71.40±0.07	18.18	66.76±0.07	23.49
	35	87.22±0.05	66.91±0.05	23.29	61.04±0.16	30.02
	64	87.27±0.03	64.61±0.08	25.97	59.22±0.06	32.14
Turmeric rhizomes (germplasm material)	7	65.54±0.06	64.56±0.09	1.50	63.97±0.11	2.40
	14	65.46±0.02	60.64±0.11	7.36	60.05±0.06	8.26
	21	65.53±0.04	57.01±0.07	13.00	55.34±0.10	15.55
	28	65.55±0.03	52.97±0.05	19.19	49.97±0.04	23.77
	35	65.48±0.03	49.68±0.06	24.13	45.59±0.07	30.38
	64	65.50±0.02	47.70±0.08	27.18	43.79±0.16	33.15

Table 3: Curcumin (g/100g) in turmeric rhizomes at different moisture levels

Spices and part	Days	Normal moisture level (Control, T_3)	5% Moisture Level (T_1) (more than normal)		10% Moisture Level (T_2) (more than normal)	
			Curcumin (g/100g)	Degradation (%)	Curcumin (g/100g)	Degradation (%)
Turmeric rhizomes (var. BSR-2)	7	4.477 ± 0.01	4.462 ± 0.01	0.34	4.458 ± 0.04	0.42
	14	4.476 ± 0.01	4.452 ± 0.01	0.54	4.447 ± 0.01	0.65
	21	4.476 ± 0.02	4.447 ± 0.03	0.65	4.443 ± 0.02	0.74
	28	4.475 ± 0.03	4.440 ± 0.02	0.78	4.437 ± 0.03	0.85
	35	4.477 ± 0.03	4.439 ± 0.01	0.85	4.435 ± 0.01	0.94
	64	4.476 ± 0.02	4.436 ± 0.04	0.89	4.432 ± 0.01	0.98
Turmeric rhizomes (germplasm material)	7	3.601 ± 0.02	3.575 ± 0.03	0.86	3.573 ± 0.01	0.92
	14	3.603 ± 0.01	3.568 ± 0.01	1.03	3.562 ± 0.02	1.19
	21	3.606 ± 0.03	3.562 ± 0.01	1.14	3.556 ± 0.02	1.30
	28	3.600 ± 0.01	3.553 ± 0.02	1.39	3.550 ± 0.01	1.47
	35	3.602 ± 0.01	3.545 ± 0.04	1.64	3.540 ± 0.03	1.78
	64	3.607 ± 0.02	3.541 ± 0.03	1.78	3.533 ± 0.02	2.00

Table 4: Total sugars (mg/g) in turmeric rhizomes at different moisture levels

Spices and part	Days	Normal moisture level (Control, T_3)	5% Moisture Level (T_1) (more than normal)		10% Moisture Level (T_2) (more than normal)	
			Total Sugars (mg/g)	Degradation (%)	Total Sugars (mg/g)	Degradation (%)
Turmeric rhizomes (var. BSR-2)	7	34.15 ± 0.03	32.12 ± 0.05	5.94	31.87 ± 0.05	6.68
	14	34.12 ± 0.05	30.20 ± 0.07	11.49	29.90 ± 0.06	12.37
	21	34.18 ± 0.02	29.01 ± 0.08	15.13	27.97 ± 0.08	18.17
	28	34.11 ± 0.03	27.25 ± 0.06	20.11	26.14 ± 0.04	23.37
	35	34.17 ± 0.06	25.92 ± 0.09	24.14	24.70 ± 0.06	27.71
	64	34.19 ± 0.04	24.86 ± 0.06	27.29	23.89 ± 0.03	30.13
Turmeric rhizomes (germplasm material)	7	33.00 ± 0.03	30.24 ± 0.06	8.36	28.62 ± 0.04	13.27
	14	33.03 ± 0.03	28.21 ± 0.08	14.59	27.30 ± 0.10	17.35
	21	33.08 ± 0.04	26.15 ± 0.04	20.95	25.11 ± 0.05	24.09
	28	33.01 ± 0.04	24.25 ± 0.07	26.54	23.07 ± 0.07	30.11
	35	33.02 ± 0.05	22.68 ± 0.05	31.31	21.46 ± 0.06	35.01
	64	33.06 ± 0.04	21.00 ± 0.12	36.48	19.79 ± 0.08	40.14

Table 5: Reducing sugars (mg/g) in turmeric rhizomes at different moisture levels

Spices and part	Days	Normal moisture level (Control, T_3)	5% Moisture Level (T_1) (more than normal)		10% Moisture Level (T_2) (more than normal)	
			Reducing Sugars (mg/g)	Degradation (%)	Reducing Sugars (mg/g)	Degradation (%)
Turmeric rhizomes (var. BSR-2)	7	8.94 ± 0.03	8.56 ± 0.06	4.25	8.34 ± 0.03	6.71
	14	8.87 ± 0.04	8.01 ± 0.04	9.70	7.87 ± 0.05	11.27
	21	8.91 ± 0.06	7.60 ± 0.04	14.70	7.32 ± 0.06	17.85
	28	8.88 ± 0.02	7.15 ± 0.03	19.48	6.95 ± 0.03	21.73
	35	8.95 ± 0.02	6.72 ± 0.01	24.92	6.52 ± 0.04	27.15
	64	8.93 ± 0.04	6.51 ± 0.02	27.10	6.31 ± 0.05	29.34
Turmeric rhizomes (germplasm material)	7	8.48 ± 0.02	7.94 ± 0.03	6.37	7.56 ± 0.06	10.85
	14	8.46 ± 0.04	7.48 ± 0.06	11.58	7.05 ± 0.04	16.67
	21	8.50 ± 0.03	7.12 ± 0.07	16.24	6.45 ± 0.02	24.12
	28	8.45 ± 0.05	6.14 ± 0.05	27.34	5.60 ± 0.05	33.73
	35	8.51 ± 0.03	5.48 ± 0.08	35.61	5.13 ± 0.04	39.72
	64	8.53 ± 0.02	5.37 ± 0.04	37.05	4.89 ± 0.02	42.67

Table 6: Non-reducing sugars (mg/g) in turmeric rhizomes at different moisture levels

Spices and part	Days	Normal moisture level (Control, T_3)	5% Moisture Level (T_1) (more than normal)		10% Moisture Level (T_2) (more than normal)	
			Non-reducing Sugars (mg/g)	Degradation (%)	Non-reducing Sugars (mg/g)	Degradation (%)
Turmeric rhizomes (var. BSR-2)	7	25.21 ± 0.04	23.56 ± 0.07	6.55	23.53 ± 0.03	6.66
	14	25.25 ± 0.03	22.19 ± 0.05	12.12	22.03 ± 0.04	12.75
	21	25.27 ± 0.04	21.41 ± 0.04	15.28	20.65 ± 0.06	18.28
	28	25.23 ± 0.03	20.10 ± 0.06	20.33	19.19 ± 0.08	23.94
	35	25.22 ± 0.05	19.20 ± 0.03	23.87	18.18 ± 0.07	27.91
	64	25.26 ± 0.02	18.35 ± 0.08	27.36	17.58 ± 0.05	30.40
Turmeric rhizomes (germplasm material)	7	24.52 ± 0.04	22.30 ± 0.06	9.05	21.06 ± 0.03	14.11
	14	24.57 ± 0.05	20.73 ± 0.04	15.63	20.25 ± 0.04	17.58
	21	24.58 ± 0.02	19.03 ± 0.03	22.58	18.66 ± 0.02	24.08
	28	24.56 ± 0.03	18.11 ± 0.06	26.26	17.47 ± 0.03	28.87
	35	24.51 ± 0.03	17.20 ± 0.05	29.82	16.33 ± 0.06	33.37
	64	24.53 ± 0.02	15.63 ± 0.08	36.28	14.90 ± 0.05	39.26

Experimental

Plant material

Dried turmeric rhizomes of variety BSR-2 were procured from Tamil Nadu Agricultural University, Coimbatore. Germplasm material of dried turmeric rhizomes was also procured to study its chemical profile and its comparison with the released variety of turmeric (BSR-2). Healthy turmeric rhizomes were selected, cut into small pieces and ground in warring blender to obtain a fine powder.

Chemicals

Commercially available and highest purity chemicals were used for various experimental procedures. Folin-Ciocalteu reagent, aluminium chloride, sodium nitrite and concentrated sulphuric acid were obtained from Merck Specialities Pvt. Ltd. Sodium hydroxide, sodium sulphate, sodium carbonate, sodium bicarbonate, sodium potassium tartrate and gallic acid were supplied by SISCO Research Laboratories Pvt. Ltd. (SRL). Phenol, copper sulphate pentahydrate and ammonium molybdate were procured from Qualigens Fine Chemicals (gsk). Catechin was sourced from Sigma-Aldrich.

Sample preparation and extraction

Four gram of powdered sample of turmeric rhizomes was weighed, 0.2 g i.e. 0.2 mL and 0.4 g i.e. 0.4 mL of distilled water was added to the powdered samples with vigorous and uniform mixing using a mortar and pestle, to achieve 5% and 10% moisture levels, respectively in powdered samples. The samples having moisture level were packed in zip lock polythene bags and weighed immediately. This weight was referred to as initial weight. All the zip lock polythene bags were double sealed and placed in an airtight box, which was kept in refrigerator at 4 °C. Four gram of control samples i.e. powdered samples with normal moisture level were also packed in zip lock polythene bags and stored in similar conditions along with powdered samples having 5% and 10% moisture levels. All bags were weighed initially daily and latter on at 2-3 days interval to observe the loss in weight with respect to initial weight. In case of loss in weight, calculated amount of distilled water was added by 10 µL syringe and bags were zip locked properly. The powdered samples having 5% and 10% moisture levels and control samples that were stored in zip lock polythene bags used for analysis. One zip lock polythene bag of each treatment was taken out for analysis initially at one-week interval i.e. 7, 14, 21, 28 and 35 days after maintaining the moisture level and final sample was taken out at nine weeks interval i.e. 64 days after maintaining the moisture levels. The samples collected periodically were extracted using soxhlet extraction technique and acetone as a solvent. Each extraction was performed in triplicate.

Estimation of total phenols content

Total phenols were determined by the Folin-Ciocalteu method [11] using gallic acid as standard for which a calibration curve was obtained. Extracts were diluted to adjust the absorbance within calibration limits. Aliquots of 0.2 mL of each extract was added to 1.0 mL of 1mol/L Folin-Ciocalteu reagent followed by addition of 2.0 mL Na_2CO_3 (20%, w/v). The solution was mixed and volume was made up to 10.0 mL with

distilled water. After 8 min, the mixture was centrifuged at 6000 rpm for 10 min. Then the absorbance of supernatant solution was measured at 730 nm using UV-VIS double beam Spectrophotometer Model 2203 (Systronics Co.) against a blank prepared similarly but containing respective solvent instead of extracts. The amount of total phenols present in the extracts was calculated from the calibration curve and the results were expressed as milligrams of gallic acid equivalent per gram (mg GAE/g).

Estimation of flavonoids content

Flavonoids content of extracts was estimated according to the colorimetric assay [12] using catechin as standard for which a calibration curve was obtained. Extracts were diluted to adjust the absorbance within calibration limits. 1.0 mL of each extract was added to test tubes containing 4.0 mL of double distilled water and 0.3 mL of $NaNO_2$ (5%, w/v) was added. After 5 min 0.3 mL of $AlCl_3$ (10%, w/v) was added and 2.0 mL of 1M NaOH was added Immediately. The solution was mixed and total volume was made up to 10.0 mL with double distilled water. The solution was mixed thoroughly and the absorbance was measured at 510 nm using UV-VIS double beam Spectrophotometer Model 2203 (Systronics Co.) against a blank prepared similarly but containing respective solvent instead of extracts. The amount of flavonoids present in extracts was calculated from the calibration curve and results were expressed as mg catechin equivalents per gram (mg CE/g).

Estimation of curcumin content

Curcumin was estimated spectrophotometrically, as described by Rajpal [13]. Acetone extracts of turmeric were dried and redissolved in ethanol whereas ethanol extracts were taken as such. All the extracts were appropriately diluted with ethanol to adjust the absorbance within the range of 0.3-0.7. Absorbance of diluted extracts were measured at 425 nm using UV-VIS double beam Spectrophotometer Model 2203 (Systronics Co.) against ethanol as blank. Curcumin content in gram per 100 gram was calculated using the formula given below:

$$\text{Curcumin content } \left(\frac{g}{100g}\right) = \frac{0.0025 \times \text{`a'} \times \text{Volume of extract (mL)} \times \text{dilution factor} \times 100}{0.42 \times \text{wt. of sample taken (g)} \times 1000}$$

where, 'a' is the absorbance at 425 nm

Since, 0.0025 g/liter solution of curcumin in ethanol gives 0.42 absorbance value at 425 nm with 1cm path length.

Estimation of total sugars content

Total sugars were estimated by Phenol sulphuric method [14] using glucose as standard for which a calibration curve was obtained. Extracts were diluted to adjust the absorbance within calibration limits. To 1.0 mL of each extract, 2.0 mL of phenol solution (2%, w/v) was added followed by 5.0 mL concentrated sulphuric acid. Acid was added in such a way that it directly pours on the solution. The test tubes were allowed to cool for 30 minutes and absorbance of the solution was measured at 490 nm using UV-VIS-double beam spectrophotometer Model 2203 (Systronics Co.) against a blank prepared similarly but containing respective solvent instead of extracts. The amount of total sugars present in the extracts were calculated from the calibration curve and the results were expressed as milligrams per gram (mg/g).

Estimation of reducing sugars content

Reducing sugars were estimated by the method of Nelson-Somogyi method [15] using glucose as standard for which a calibration curve was obtained. Extracts were diluted to adjust the absorbance within calibration limits. To 1.0 mL of each extract, 1.0 mL distilled water was added, followed by addition of 1.0 mL alkaline copper reagent, solution was mixed, covered with aluminum foil and heated in boiling water bath for 20 min. The tubes were cooled to room temperature and 1.0 mL of arsenomolybdate reagent was added. The contents were mixed thoroughly and volume was made up to 10.0 mL with distilled water. The absorbance of the solution was measured at 520 nm using UV-VIS double beam Spectrophotometer Model 2203 (Systronics Co.) against a blank prepared similarly but containing respective solvents instead of extracts. The amount of reducing sugars present in the extracts were calculated from the calibration curve and the results are expressed as milligrams per gram (mg/g).

Estimation of non-reducing sugars content

The content of non-reducing sugars was calculated from the difference between the content of total sugars and that of reducing sugars.

Non-reducing sugars = Total sugars – Reducing sugars

Conclusion

Phytochemical constituents of turmeric rhizomes decreased under moisture conditions during storage. The presence of moisture conditions depleted the nutritive value of turmeric. Temperature and atmosphere relative humidity must be regulated to maintain quality of powdered turmeric rhizomes. Thus, the moisture dependency of physical, mechanical and chemical properties is important for storage and processing and especially for development of food products.

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