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Physico chemical quality evaluation of turmeric powder (*Curcuma longa*) stored at different temperatures

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Abstract
Studies on storage of turmeric powder packaged in a three layered metalized polyester covers (12µ polyester + 12µ metalized polyester + 80µ polyethylene (LDPE)) and stored at different temperatures like ambient, 30, 40 and 50 °C in different BOD incubators for a storage period of 10 weeks were studied. The results of the study indicated that the moisture content of turmeric powder reduced when stored at 30, 40 and 50 °C and maximum reduction of moisture content was 17.49% when stored at 50 ºC. While for ambient stored turmeric powder, the moisture content was found to increase by 7.34%. There was no change in essential oil content of turmeric powder at ambient and 30 °C which was maintained at 4% in both the cases. But a reduction in essential oil content by 10% was observed at 40 and 50 °C towards the end of the storage period. A decrease in oleoresin content with increase in storage temperature was observed and the minimum reduction of 8.50% was obtained for the ambient stored turmeric powder and maximum reduction of 19.76% was observed when stored at 50 °C. Curcumin content reduced by 4.58%, 6.26%, 7.33% and 10.38% for ambient, 30, 40 and 50 °C storage conditions, respectively towards the end of 10 weeks of storage. Volatile oil constituents in the essential oil of turmeric powder like α-terpineol, zingiberene decreased during storage while constituents like ar-curcumene and curlone, ar-tumerone increased during the storage of turmeric powder.

Keywords: Curcumin content, essential oil, oleoresin, turmeric powder

Introduction
Turmeric (*Curcuma longa* L.) is native to South east India and Indonesia. Turmeric as a whole rhizome, is processed into powder or oleoresin (Govindarajan, 1980). Ground turmeric is mostly used on the retail market, and by the food processors. Since curcuminoids, the colour constituents of turmeric, deteriorate with light and to a lesser extent, under heat and oxidative conditions, it is important that ground turmeric be packed in a UV protective packaging and appropriately stored. Turmeric powder is a major ingredient in curry powders and pastes and is used to colour and flavour food.

The quality depends upon the initial quality of rhizomes, different practices adopted during its processing, type of packaging material and storage conditions (Sampathu *et al.*, 1988; Bambirra *et al.*, 2002) [10, 4]. Packaging is an integral part of food processing, and used as a means of increasing the shelf life of foods, spices and condiments. Packaging in polymeric films results in high relative humidity within the package environment, which diminishes dehydration and preserves freshness (Sidhu *et al.*, 2013) [11]. The material of the film selected for packaging should be such that the environment provides the optimum condition for increasing the shelf life of produce. Turmeric, a colouring spice, needs protection from light. Colour, curcumin and oleoresin contents may undergo changes during storage as there is a wide gap between the harvest time of turmeric and its consumption (Bambirra *et al.*, 2002) [4].

Since the qualities of turmeric rhizomes for food and medicinal uses are based directly on the content of the curcuminoids and volatile oil, it is important that rhizomes are handled and stored correctly in order to maintain the levels of the active principles in the harvested raw material. Turmeric rhizomes are exposed to a variety of conditions during processing, packaging and storage, and some of these may have detrimental effect on the stability of the active constituents and consequently on their quality. Factors affecting the stability of active constituents of turmeric have previously been investigated (Ansari *et al.*, 2005) [1]. The content of active constituents could be affected by environmental factors such as temperature, pH, light, moisture and air (Chatterjee *et al.*, 1998) [5].

Little information is available on the effect of storage conditions on the raw and processed rhizomes on the quantity of active constituents of these rhizomes. The old-styled drugstores and commercial manufacturers usually keep turmeric rhizomes in containers such as paper or plastic bags, and as sliced or powdered forms in order to prescribe or utilize for products formulation. Therefore, it is of interest to study the effect of storage conditions on the active constituents. Hence, the present work was undertaken with the objective to study the effect of temperature during storage of turmeric powder and to study quality changes that occurs during storage of turmeric powder.

Materials and Methods

The turmeric variety-Prathibha was procured from ICAR-Indian Institute of Spice Research (ICAR-IISR), Kozhikode, Kerala. The rhizomes were cured in boiling water for 1 h and sun dried to obtain a final moisture content of less than 10%. Dry turmeric rhizomes of about 6 kg was pulverized in a hammer mill (8" grease type pulverizer with all spice contact parts fully stainless steel and 2 hp single phase motor, manufacturer: Sree Valsa Engineering Works, Coimbatore) to obtain turmeric powder (250 microns). About 100 g of turmeric powder was packaged in a three layered metalized polyester covers (12µ polyester + 12µ metalized polyester + 80µ polyethylene (LDPE)) and sealed. The packaged turmeric powder was stored at different temperatures like ambient, 30, 40 and 50 °C in different BOD incubators (Thermotech, L-7003) for a storage period of 10 weeks. Every week, three replicate packs were drawn from each incubator and various physical and biochemical properties were analyzed. During the stored period, the ambient temperature varied from 28 to 35 °C while the relative humidity varied from 40 to 85%.

Biochemical analysis

Moisture content of the sample was analysed in a fully automatic moisture balance (Shimadzu, MOC-120H). Water activity of the sample was analysed in a water activity meter (Aqualab lite, Decagon). Colour of sample was determined using colour meter (Colorflex EZ, Hunter Lab, 45/0 LAV). Total carbohydrates were estimated by phenol sulphuric acid method (Dubois *et al.*, (1956) [7]. The Soxhelet extraction method was used to estimate fat. Protein was estimated by different methods as described by Lowry and also by estimating the total nitrogen content (Lowry *et al.* (1951) [9]. Starch was estimated by Anthrone method where the starch was hydrolysed into simple sugars by dilute acids and the quantity of simple sugars is measured calorimetrically.

Essential oil was estimated as per the method described by AOAC (1975) [2] using modified Clevenger apparatus. Oleoresin content of the spice sample was estimated by the method of ASTA (1968). The curcumin content was estimated as per procedure given by ASTA, 1968. The volatile constituents of essential oil by gas chromatography mass spectroscopy using a gas chromatograph (Shimadzu GC 2010) equipped with mass spectroscope (Shimadzu QP-2010) and capillary column (RTX-Wax, 30m × 0.25mm id × 0.25µm). The column temperature was programmed as Injection port temperature: 250 °C, Flow rate: 1 ml/min, Carrier gas: helium with linear velocity of 48.1 cm/s, Split ratio: 50, Ionization energy: 70 eV, Mass range: 40-650 amu 0.1µl of essential oil was injected into the equipment through the injection port. The sample run was set to 54 min and peaks were obtained. The peaks on the chromatogram was analysed by the inbuilt library of the gas chromatogram unit. The constituents present in the oil were quantified by the mass spectrogram and the quantity of constituents was estimated.

A two factor completely randomized block design was followed to determine the effect of storage temperature (30, 40, 50 °C and ambient) and storage period (0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 weeks) on various physical and biochemical properties of stored turmeric powder.

Results and Discussion

The initial physical and biochemical properties of dry turmeric rhizomes were determined and are tabulated in Table 1. From the table, it was noticed that the moisture content of the dry turmeric rhizome were 8.52%. Also, the important biochemical properties in dry rhizome like essential oil content, oleoresin content and curcumin content were 4.40%, 17.64% and 6.71%, respectively.

Table 1: Physical and biochemical properties of turmeric rhizome

Property	Parameters	Value
Physical Properties		
	Moisture content, %	8.52
	Water activity	0.524
	Colour	L*- 41.73 a*- 19.01 b*-3 8.30
Biochemical properties		
Primary metabolites	Carbohydrate, %	67.24
	Fat, %	9.75
	Protein, %	3.37
	Starch, %	59.53
Secondary metabolites	Essential oil, %	4.40
	Oleoresin, %	17.64
	Curcumin content, %	6.71

Quality changes during storage

The whole turmeric (variety Prathiba) was pulverized in a hammer mill to obtain turmeric powder of size 250 microns. The turmeric powder was packaged in three layered metalized polyester covers (12µ polyester + 12µ metalized polyester + 80µ polyethylene (LDPE)) and stored for a period of 10 weeks at different storage temperatures of 30, 40 and 50 °C and the control was stored at ambient temperature. The ambient temperature varied from 22 to 35 °C and RH varying from 35 to 75%. The stored turmeric powder was analysed for various physical and biochemical properties.

Variation in physical properties of stored turmeric powder

The physical properties of turmeric powder like moisture content, water activity and colour were determined every week for the entire storage period of 10 weeks.

Moisture content

The initial moisture content of turmeric powder was 8.46% and after storage for 10 weeks at temperatures of 30, 40 and 50 °C, it was observed that moisture content decreased to 7.92, 7.45 and 6.98%, respectively (Fig.1). From the figure, it was observed that maximum reduction in moisture content of 17.49% was found in turmeric sample when it was stored at a temperature of 50 °C. However, it was observed that turmeric powder when stored at ambient conditions for 10 weeks, showed an increase in moisture content of 7.34%, over the initial moisture content. The analysis of variance indicated that that the variation in moisture content of stored turmeric powder with respect to independent variables i.e. temperature, storage period and their interactions were highly significant ($p \leq 0.01$).

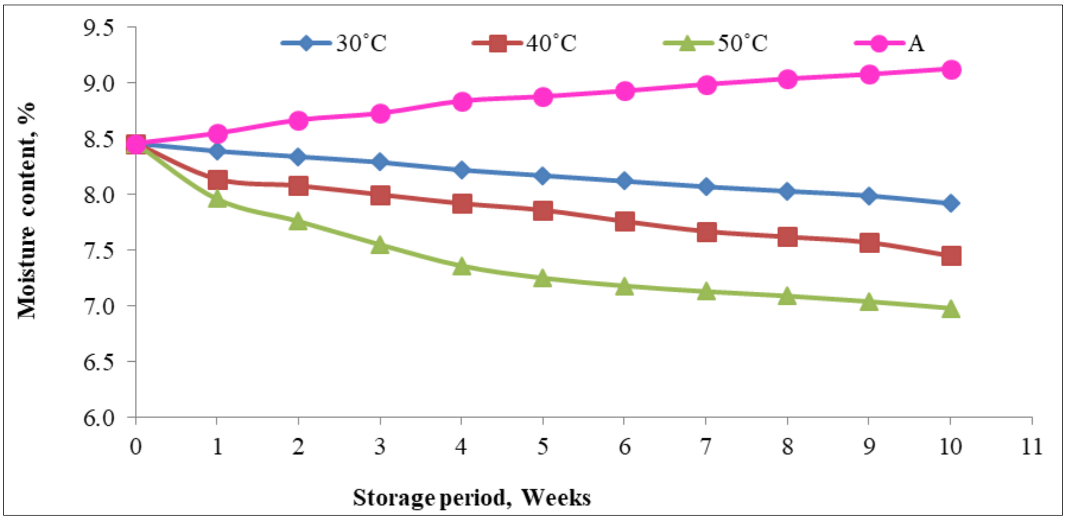

Fig 1: Variation in moisture content at different storage temperatures

Bambirra *et al.*, (2002) [4] reported that moisture content of ground turmeric changed from 9.86% to 12.24% during 60 days of storage in polyethylene pack at ambient condition. Lahari *et al.*, (2020) [8], reported that during storage of local variety turmeric powder under ambient conditions in different packaging materials for 180 days the final moisture content of the cured dried turmeric powder increased from 14.60% (db) to 16.77% (db), 16.65% (db), 15.88% (db), 15.82% (db) and 15.66% (db) for LLDPE, LDPE, steel container, glass container and plastic container respectively.

Water activity

During storage of turmeric powder, under various temperatures, a decrease in water activity was observed (Fig. 2). From the figure, it was observed that water activity decreased from an initial value of 0.51 to 0.44, showing a decrease in water activity by 13.73% for turmeric powder stored at 50ºC. It was however observed that the turmeric powder when stored at ambient condition for 10 weeks, the water activity increased from 0.508 to 0.557, showing an increase of 8.93% towards the end of storage period. The analysis of variance indicated that the variation in water activity of stored turmeric powder with respect to independent variables i.e. temperature and storage period and their interaction were highly significant ($p \leq 0.01$).

According to Souza *et al.*, (1997) [13], water activity did not affect the stability of curcuminoid pigments in curumin and turmeric microcrystalline cellulose model system during storage at 21 °C.

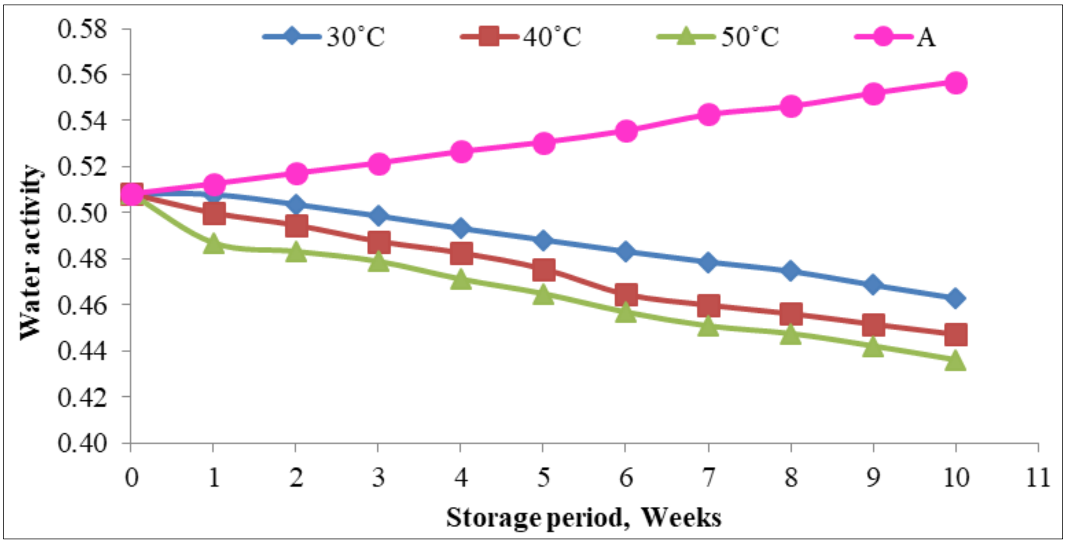

Fig 2: Variation in water activity at different storage temperatures

Colour values

Initial the colour values L*, a* and b* of turmeric powder were 45.62, 21.69 and 46.91, respectively. Fig. 3, 4 and 5 shows the variation in colour values at different temperatures of 30, 40 and 50 °C for various storage periods. It was found that the colour values L*, a* and b* increased during storage under at all the storage temperatures and after storage period of 10 weeks, at 50 °C, the values varied as 49.82, 24.84 and

60.99, respectively. The analysis of variance indicated that the changes in colour values of turmeric powder with respect to variation in temperature, storage period and their interaction were highly significant (*p*≤0.01).

Sowbhagya *et al.*, (2005) [14] reported that brightness of extruded balls made from corn and defatted soybean flours which when coated with curcumin reduced by 30% during storage for 10 weeks at ambient condition.

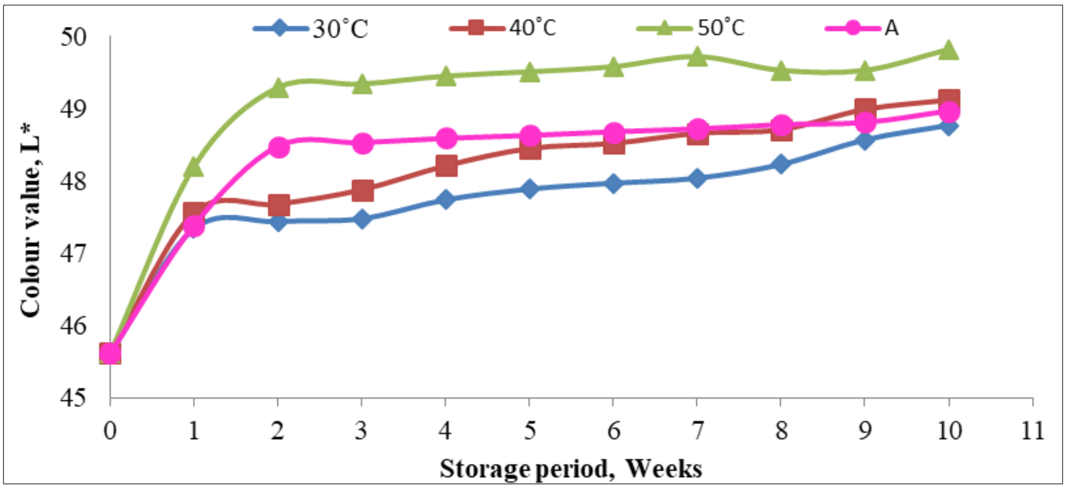

Fig 3: Variation in colour value (L*) at different storage temperatures

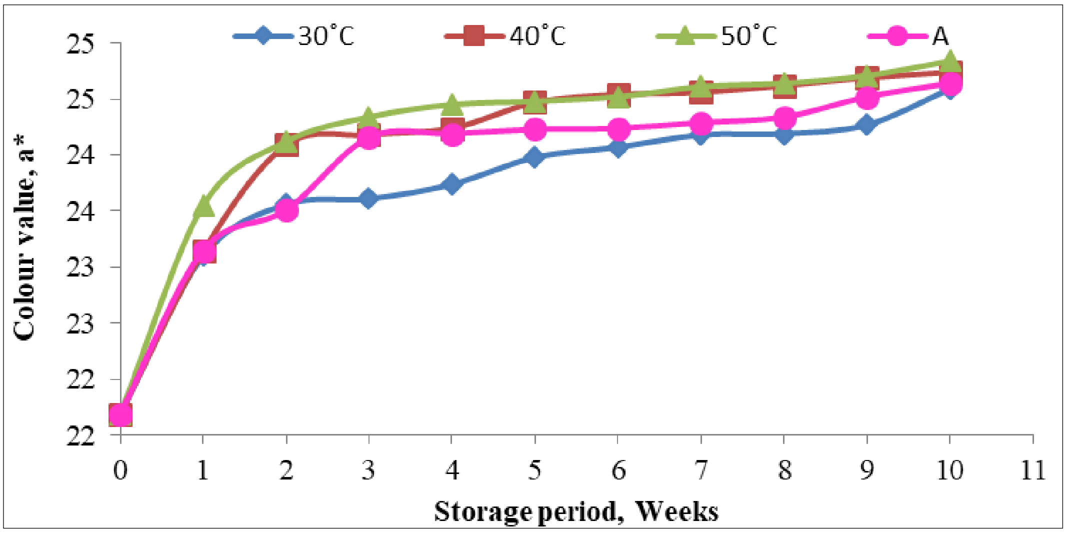

Fig 4: Variation in colour value (a*) at different storage temperatures

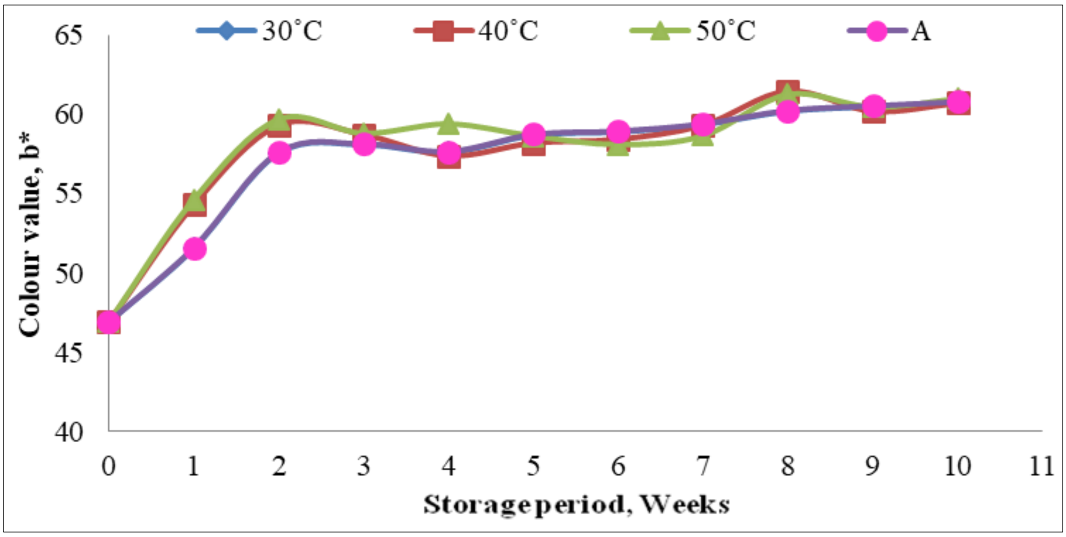

Fig 5: Variation in colour value (b*) at different storage temperatures

Variation in biochemical properties of stored turmeric powder

Primary metabolites

The primary metabolites like carbohydrate, protein, fat and starch were determined initially and finally at the end of storage period and are presented in Table 2. It was observed that during storage at 50 °C for 10 weeks, the carbohydrate content decreased from 67.24% to 67.16% showing a reduction of 0.08%. Protein content has changed from 9.75% to 9.65% showing a reduction of 1.03% at the end of tenth week of storage at 50 °C. The fat content reduced from 3.37% to 3.33% and starch from 59.53% to 59.46% at the end of tenth week of storage at 50 °C. The study indicated that there was no drastic change in primary metabolites during storage of turmeric powder.

Matsuki *et al.*, (2003) [16] reported that starch content in wheat kernel was reduced in response to increased maturation temperature from 15 to 30 °C. Wolf *et al.*, (1982) [17] reported that there was a decrease in fatty acids (linolenic and linoleic acids) in soya bean seed as the temperature increased from 18 to 33 °C.

Secondary metabolites

The secondary metabolites of stored turmeric powder studied were essential oil, oleoresin and curcumin content.

Essential oil

Variation in essential oil content of turmeric powder stored at different temperatures and storage periods is presented in Fig. 6. It illustrates that essential oil content decreased from an initial value of 4.0% to 3.6% at the end of 10 weeks of storage, showing a reduction of 10% at 40 °C and 50 °C of storage. It was however observed that the turmeric powder when stored at ambient condition and 30°C, there was no change in the essential oil (4.00%) till the end of storage for 10 weeks. The analysis of variance indicated that temperature, storage period and their interaction has influenced the essential oil significantly ($p \leq 0.01$).

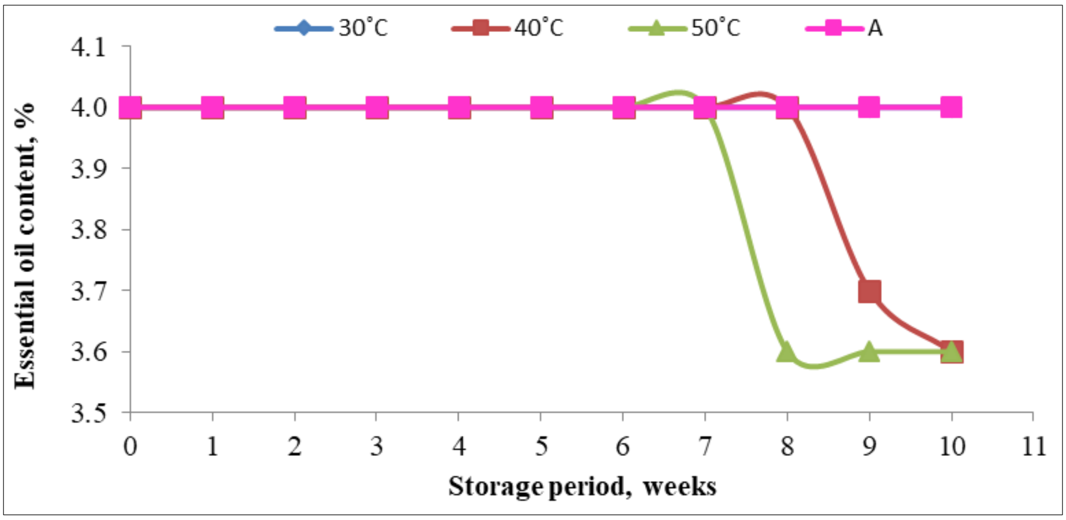

Fig 6: Variation in essential oil at different storage temperatures

Subhadhirasakul *et al.*, (2007) [15] reported that there was no change in volatile oil content of turmeric rhizome till 3 months of storage at room temperature.

Table 2: Effect of temperature on primary metabolites during storage of turmeric powder

S. No.	Turmeric powder	Temperature	Carbohydrate (%)	Protein (%)	Fat (%)	Starch (%)
1.	Initial	Ambient	67.24	9.75	3.37	59.53
2.	Final	30°C	67.21	9.72	3.36	59.51
		40°C	67.18	9.68	3.34	59.48
		50°C	67.16	9.65	3.33	59.46
		Ambient	67.21	9.73	3.36	59.52

Oleoresin content

The variation in oleoresin content at different temperatures during storage period is given in Fig 7. From the figure, it was observed that the oleoresin content decreased from 15.89% to 12.75% at the end of 10 weeks of storage, showing a maximum reduction of 19.76% at 50°C of storage. It was observed that oleoresin content decreased with increase in temperature and maximum retention of oleoresin was obtained in turmeric powder that was stored at ambient temperature with a minimum loss of 8.50%. The analysis of variance indicated that the variation in oleoresin content of stored turmeric powder was significantly ($p \leq 0.01$) influenced by storage temperature, storage period and their interactions.

Singh *et al.*, (2010) [12] reported that there was a decrease in oleoresin content from 11.1% to 9.9% as the temperature increased from 45 to 65 ºC in turmeric mother rhizome. Lahari *et al.*, (2020) [8], reported that during storage of local variety turmeric powder under ambient conditions in different packaging materials for 180 days, the oleoresin content of the cured dried turmeric powder decreased 10.30% to 7.01%, 7.33%, 8.67%, 8.84%and 9.34% for LLDPE, LDPE, glass container, steel container and plastic container, respectively.

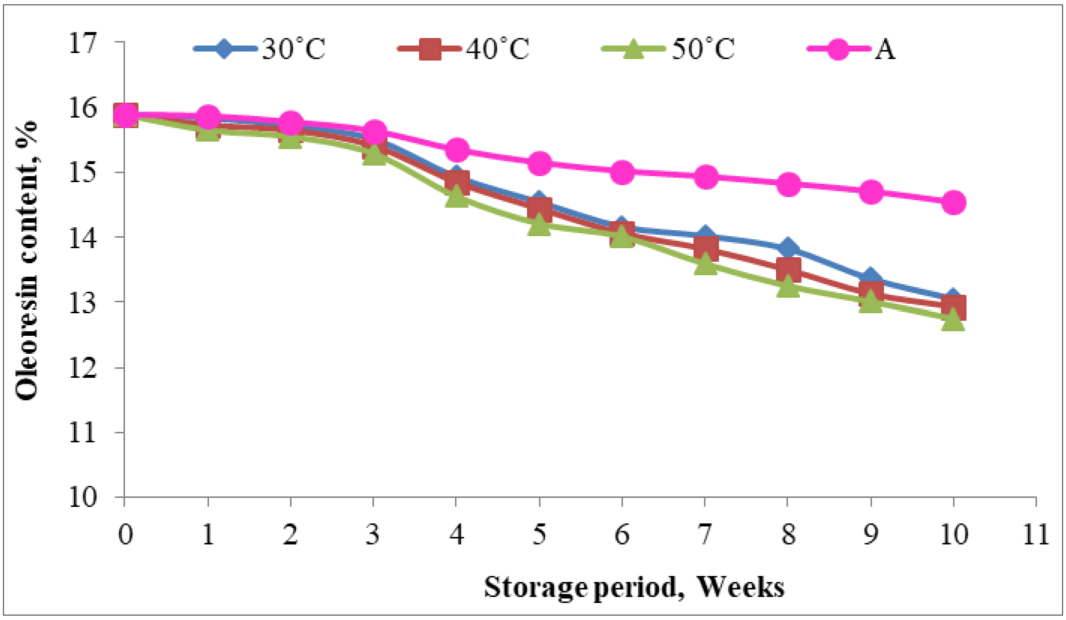

Fig 7: Variation in oleoresin content at different storage temperatures

Cur cumin content

Fig. 8 depicts the variation in curcumin content of stored turmeric powder at different temperatures for various storage periods. From the figure, it was noticed that the curcumin content declined to 6.26%, 7.33% and 10.38% during storage at temperatures of 30, 40 and 50°C, respectively. But for turmeric powder stored at ambient conditions, the curcumin content changed from 6.55% to 6.25%, showing a reduction of 4.58%. It was observed from the table that the increase in temperature decreased the curcumin content of turmeric powder. Analysis of variance showed that temperature, storage period and their interactions had significant on curcumin content of stored turmeric powder ($p \leq 0.01$).

Sidhu *et al.*, (2013) [11] reported that curcumin content in rhizome and turmeric powder decreased linearly with storage period under ambient as well as refrigerated storage condition. The curcumin content in turmeric powder was decreased to 38.46% and 26.15% in polypropylene pouch under ambient and refrigerated conditions after 180 days of storage. Lahari *et al.*, (2020) [8], reported that during storage of local variety turmeric powder under ambient conditions in different packaging materials for 180 days, the curcumin content decreased from 3.11% to 1.72%, 2.39%, 2.40% and 2.67% for LLDPE, LDPE, glass container, steel container and plastic container, respectively.

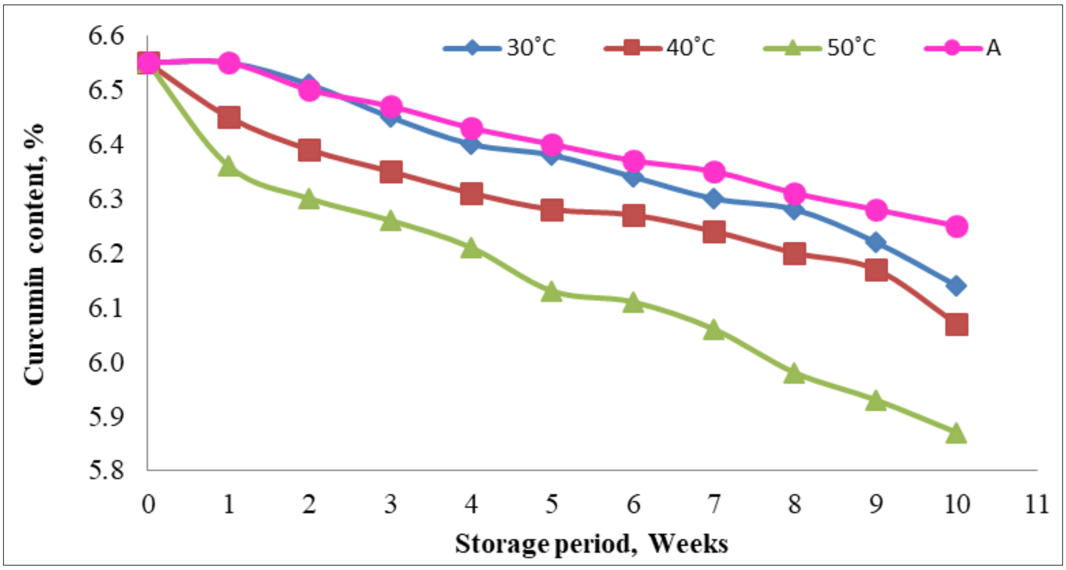

Fig 8: Variation in curcumin content at different storage temperatures

Variation in volatile oil constituents of stored turmeric powder

The volatile constituents of essential oil of stored turmeric powder were analysed using GC-MS. The important volatile constituents present in turmeric oil were eucalyptol, cymene, trans (β) caryophyllene, alpha-terpineol, zingiberene, β-sesquiphellandrene, ar-crcumene, tumerone, curlone and ar-tumerone and the quantity of each constituent is tabulated in Table 1.

Table 3 represents the variation in the volatile constituents of essential oil of turmeric powder stored at different temperatures for various storage periods. For constituents like α-terpineol, zingiberene and tumerone, there was a decrease in the level at different temperature for storage period of 10 weeks. And constituents like ar-curcumene and curlone showed an increase in level. Analysis of variance showed that temperature, storage period and their interaction were highly significant on the volatile constituents of essential oil ($p \leq 0.01$).

Chatterjee *et al.*, (1999) [6] reported that there was no qualitative difference in the GLC profile of the dry turmeric and γ-irradiated samples. The major compounds identified were α-phellandrene, p-cymene, 1:8cineol, β-caryophyllene, ar-curcumene, zingeberene, β-sesquiphellandrene, nerolidol, turmerone, ar-turmerone, curlone and dehydrozingerone.

Tables 3: Variation in volatile oil constituents during storage of turmeric powder

Constituents	Initial content, %	Final content after 10 Weeks (180 days) of storage under different storage temperatures, %			
		30 °C	40 °C	50 °C	Ambient
Eucalyptol (%)	0.44	0.45	0.46	0.50	0.22
cymene	0.22	0.23	0.23	0.25	0.14
Trans (β) caryophyllene	0.24	0.23	0.22	0.22	0.29
Alpha terpineol	0.08	0.06	0.06	0.06	0.04
Zingiberene	1.95	1.93	1.92	1.86	1.98
β- sesquiphellandrene	3.11	3.35	3.12	2.98	3.40
Ar- curcumene	1.12	1.28	1.42	1.47	1.23
Tumerone	23.71	23.45	22.70	22.50	23.40
Curlone	5.67	8.44	7.91	7.98	8.49
ar- turmerone	16.72	14.36	14.35	13.32	14.31

Conclusion

The study concluded that storage of turmeric powder for a period of 10 weeks at ambient temperature could retain maximum percentage of essential oil, oleoresin and curcumin with a loss corresponding to 0, 8.56 and 4.58% of the initial content. With the increase in storage temperature to 50 °C, the loss in essential oil, oleoresin and curcumin content were 10, 19.76 and 10.38%, respectively which clearly indicated that at higher temperatures the degradation of volatiles constituents in turmeric were higher.

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