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Photo-selective nets and metabolic elicitors influences the colour values of turmeric (*Curcuma longa* L.) powder

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Abstract
Turemric variety 'IISR-Prathibha' was grown under different photo-selective nets and sprayed with metabolic elicitors at different growth stages. The powder, obtained after processing the harvested rhizomes varied significantly for colour values and composition as analysed using a Lovibond R LC Chroma-Meter. A combination of providing yellow net and spraying with salicylic acid at 100 ppm was found to be highly beneficial for obtaining turmeric powder with maximum *b** value, which is a major indicator of the colour value (55.20, 54.10 and 54.65 respectively) and was significantly superior over all other treatment combinations used in the study. Optimised growing environments by way of making provision for cultivating turmeric crop under photo-selective nets coupled with the application of a suitable metabolic elicitor may be considered as revealed in the present study to obtain turmeric powder of high quality with better consumer and industry preference.

Keywords: Turemric, photo-selective nets, metabolic elicitors, colour values

Introduction
Instrumental colour values offer the objective estimation of the colour components of samples and thus eliminate the human error in judging and perceiving any colour. Different people interpret the expressions of colour in many different ways. Thus, subjective expression of colour may not be accurate enough to communicate the colour. Further, when the variation in the hue of the same colour to be evaluated, the chances of erring will certainly be more for the product like turmeric powder and therefore, in the present study, the colour evaluation was done using a standard colour meter. Hitherto, the colour analysis was rather subjective, which led to lot of variation when done by different subjects and therefore, bringing objectivity and uniformity in the colour values of turmeric powder is essential to arrive at globally accepted norms. Objective approaches in colour measurement and expression would help minimize communication between processors and buyers would be much simpler and exact (Lee, 2000) [5]. In the case of instrumental measurement, colour is expressed by means of the colour coordinates. Colour may be determined instrumentally using either colorimeters or spectrophotometers.

Colour is an important quality attribute in the food and bioprocess industries, and it influences consumer's choice and preferences. Food colour is governed by the chemical, biochemical, microbial and physical changes which occur during growth, maturation, postharvest handling and processing. The colour of food is the first quality parameter evaluated by consumers, and it is critical to product acceptance (Pathare *et al.*, 2013) [8]. Food appearance determined mostly by surface colour is the first sensation that the consumer perceives and uses as a tool to either accept or reject food (Leon *et al.*, 2006) [6].

Assessment of colour is often more than a numeric expression. Usually it is an assessment of the colour difference of a sample relative to a known standard or reference. Difference in $L^*a^*b^*$ values can both be used to compare the colours of two objects. In the present study, the variation in these $L^*a^*b^*$ values as influenced by various photo-selective nets, metabolic elicitors and their interaction on the final colour of the ground turmeric powder when the turmeric crop was grown under different photo-selective nets and sprayed with metabolic elicitors was studied for two successive growing seasons.

The parameter a^* takes positive values for redness and negative values for the greenness, whereas b^* takes positive values for yellowness and negative values for the blueness. Colour parameters a^* and b^* extend from –60 to +60 (Pal *et al.*, 2020) [7]. L^* is a measurement of luminosity, which is the property according to which each colour can be considered as

equivalent to a member of the greyscale, between black and white (Granato and Masson, 2010) [1] and it corresponds to a dark-bright scale and represents the relative lightness of colours with a range from 0 to 100 (0 = black, 100 = white).
The present study was conducted with a view to understand the impact of different photo-selective nets and metabolic elicitors on the final colour of the turmeric powder as colour is one of the major quality attributes based on which consumers or industries buy the powder besides curcumin, essential oil and other quality attributes.

Material and methods

The field experiment was carried out at Tayur village of Nanjangud Taluk, Mysuru district of Karnataka, India at a farmer's field. The study was conducted during two *kharif* seasons *viz.*, from June 2018 to February 2019 and June 2019 to February 2020. The experiment was laid out in split plot design with three replications and 'IISR Prathibha' variety was used.
Main plots : Photo-selective nets (25% shading)

- S1 : R (Red)
- S2 : B (Blue)
- S3 : Y (Yellow)
- S4 : W (White)
- S5 : Open field (without shade net)

Sub plots : Metabolic elicitors (E)

- E1– Chitosan 100 ppm
- E2 – Salicylic acid 100 ppm
- E3 – Dry yeast 5 g l^{-1}
- E0 – Control (Distilled water spray)

Note: Elicitors were sprayed at monthly intervals till 180 days of planting the crop

After harvesting the rhizomes upon attaining the maturity, they were cleaned and processed as per the standard procedure (reference??) and the ground powder thus obtained was subjected for colour measurement using a Lovibond R LC Chroma-Meter at the Department of Post-harvest Technology, College of Horticulture, University of Horticultural Sciences Bagalkote, Bengaluru campus based on the *L** (lightness or brightness), *a** (redness/greenness), *b** (yellowness/blueness) values.

Results

Photo-selective nets, metabolic elicitors and their interaction brought out significant changes in the colour composition of the ground samples of cured turmeric rhizomes. Among the photo-selective nets, highest *L** values were recorded for the powder obtained from the cured rhizomes of turmeric plants grown under yellow net (59.55, 59.61 and 59.58, respectively for 2018-19, 2019-20 and over two years), which corresponds to the more brightness of the powder. This treatment was superior over all other samples taken from plants grown under other shade nets and open field conditions. The lowest *L** values were recorded in samples obtained from plants grown under red net (55.62, 55.55 and 55.58, respectively) 2018-19, 2019-20 and over two years. Likewise, elicitors also had highly significant impact in respect of *L** values, where in, plants applied with dry yeast at 5000 ppm recorded maximum *L** values (58.63, 58.50 and 58.56) closely followed by the application of salicylic acid 100 ppm (58.59, 58.51 and58.55) which were *at par* and differed significantly from other two treatments tried during 2018-19, 2019-20 and over two years.
With regard to interaction effect, *L** values, maximum values were recorded in plants grown under yellow net and treated with salicylic at 100 ppm (62.92, 62.75 and 62.83, respectively) during 2018-19, 2019-20 and over two years, which was significantly superior over rest of the treatment combinations tried.
In respect of *a** value, the maximum value was recorded in plants grown under yellow net (24.71, 24.56 and 24.63 during 2018-19, 2019-20 and over two years, respectively) which was significantly distinct over all other nets tried and open field conditions. The lowest *a** value was noticed in plants grown under blue net (23.18, 23.15 and 23.16, respectively) during 2018-19, 2019-20 and over two years respectively. The influence of various elicitors tried was also highly significant with maximum *a** value (25.58, 25.50 and 25.54 respectively) in plants applied with dry yeast at 5000 ppm which differed significantly from rest of the treatments tried. The interaction effect of shade nets and elicitors on the *a** value of ground rhizome powder was highly significant, with plants grown under yellow net sprayed with dry yeast at 5000 ppm recording maximum *a** value (26.88, 26.60 and 26.74) which differed significantly from rest of the treatment combinations. This treatment proved to enhance the appearance of ground turmeric powder showing a tendency towards higher redness. None of the treatments showed a tendency to give green appearance to the ground turmeric powder.
The major physical parameter that determines the quality and appearance of ground turmeric spice is *b** value. Higher the value, better the visual quality. None of the treatments tried during the course of investigation either singly or in combination, showed the tendency towards attributing blue colour. Provision of yellow net for the turmeric plants resulted in high quality turmeric powder with maximum b* value (50.27, 49.20 and 49.73, respectively) during 2018-19, 2019-20 and over two years, which was *at par with* powder obtained from the rhizomes of plants grown under open field conditions (49.80, 48.80 and 49.30). Superior quality turmeric powder with maximum *b** value was obtained from plants applied with no elicitor during 2018-19 (50.01). However, the best quality turmeric powder with maximum *b** value was obtained with the application of salicylic acid at 100 ppm (48.67 and 49.17, respectively) which was *at par* with the application of dry yeast at 5000 ppm (48.19 and 48.44, respectively) during 2019-20 and over two years. A combination of providing yellow net and spraying with salicylic acid at 100 ppm was found to be highly beneficial in giving turmeric powder with maximum *b** value (55.20, 54.10 and54.65, respectively) which was significantly superior over all other treatment combinations. The lowest *b** value was recorded in plants grown under white net and treated with chitosan 1000 ppm during 2018-19 and over two years (40.97 and 41.17, respectively), while minimum *a** value was found in plants grown under red net without any elicitor treatment which was *at par* with S4E1 (41.38) and S2E1 (41.65).

Discussion

Among various photo-selective nets (Table 1), the highest *L** values were recorded for the powder obtained from the cured rhizomes of turmeric plants grown under yellow net (59.55, 59.61 and 59.58 for 2018-19, 2019-20 and over two years, respectively), which corresponds to the higher brightness of the colour. This is in concurrence with the findings of Meena *et al.* (2016) in pomegranate, where the fruits exposed to direct sunlight in the open condition developed a poor colour (39.3 *L**) mainly because of the exposure to high temperature resulting in low anthocyanin content. As per Madhusankha *et* *al.* (2018) [3], *L** value of 64.74 for the standard curcumin sample has been reported. Further, they found higher *L** values for the samples with higher curcumin, which is in contrary to the results obtained in the present investigation, wherein, the highest curcumin was recorded in the plants grown under blue photo-selective net (Unpublished data of the same author). It is not only curcumin, which is responsible for the final colour of the powdered sample, other compounds like methoxy curcumin and bis-de-methoxy curcumin also contribute, which may be the reason for getting highest *L** value for the powder obtained from the plants grown under the yellow photo-selective net. Metabolic elicitors also had highly significant impact in respect of *L** values, wherein, plants applied with dry yeast at 5000 ppm recorded maximum *L** values (58.56 pooled), closely followed by the application of salicylic acid at 100 ppm (58.55 pooled) which were *at par* and differed significantly from chitosan 1000 ppm and control (distilled water) treatments. With regard to interaction effect, *L** values which determines the appearance of turmeric powder, maximum value was recorded in plants grown under yellow net and treated with salicylic at 100 ppm (62.83 pooled), which was significantly superior over rest of the treatment combinations tried.

In respect of *a** value, which again determines the appearance of the turmeric powder, the maximum value was recorded in plants grown under yellow net over two seasons (24.63) which was significantly distinct over all other nets tried and open field conditions. The lowest *a** value was noticed in plants grown under blue net as per pooled data (23.16 pooled value). The influence of various metabolic elicitors tried was also highly significant with maximum *a** value of 25.54 over two years in the plants applied with dry yeast at 5000 ppm which differed significantly from rest of the treatments. The interaction effect of nets and elicitors on the *a** value of ground rhizome powder was highly significant, with plants grown under yellow net sprayed with dry yeast at 5000 ppm recording maximum *a** value of 26.74 over two years, which differed significantly from rest of the treatment combinations. This treatment proved to enhance the appearance of ground turmeric powder showing a tendency towards higher redness (Table 1).

Provision of yellow net for the turmeric plants resulted in high quality turmeric powder with maximum *b** value (49.73 considering two years data, which was *at par with* the powder obtained from the rhizomes of the plants grown under open field conditions (49.30. However, the best quality turmeric powder with maximum *b** value was obtained with the application of salicylic acid at 100 ppm (48.67 and 49.17, respectively), which was *at par* with the application of dry yeast at 5000 ppm (48.19 and 48.44, respectively) during 2019-20 and over two years. Higher *b** value in yellow net coupled with salicylic acid at 100 ppm combination, may be due to the higher rhizome essential oil obtained in this study and there is a positive correlation between these two traits.

A combination of providing yellow net and spraying with salicylic acid at 100 ppm was found to be highly beneficial for obtaining turmeric powder with maximum *b** value (55.20, 54.10 and 54.65 respectively) which was significantly superior over all other treatment combinations. The lowest *b** value was recorded in plants grown under white net and treated with chitosan 1000 ppm during 2018-19 and over two years (40.97 and 41.17 respectively), while minimum *a** value was found in plants grown under red net without any elicitor treatment during 2019-20 (Table 1 and Plate.1-3). Negative and highly significant correlation between the *b** value and curcumin content (Table 1) in the present study is a clear indication of the role of other factors in the colour composition and value of the ground turmeric powder. On the contrary, Madhusankha *et al.* (2018) [3], reported a linear relationship between the curcumin content and the *b** value. Growing conditions, light quality, soil and climatic variables, other quality parameters like essential oil, ar-turmerone may influence the overall colour composition of the turmeric powder, which needs further elucidation.

The colour of the turmeric powder also depends on the kind of soil in which it is grown, the pH, nutrient elements as reported by Hossain and Ishimine (2005), who recorded deepest yellow powder when turmeric was grown on dark red soil followed by grey soil. Different growing environments also lead to differences in the final colour of the ground turmeric as Peter (2020) obtained different colour values from the turmeric powder from the plants grown at different villages of Idukki district in Kerala. Probably further experimentation by growing under different edaphic conditions coupled with the best photo-selective net (yellow in the present case) and the best elicitor (salicylic acid at 100 ppm) may result in the best final product in terms of colour.

Table 1: Impact of photo-selective nets, metabolic elicitors and their interaction on colour composition of turmeric powder (*L*a*b**)

Main treatments (M)	*L**			*a**			*b**		
	18-19	19-20	Pooled	18-19	19-20	Pooled	18-19	19-20	Pooled
S1 (Red net)	55.62^{d}	55.55^{c}	55.58^{d}	23.55^{bc}	23.49^{b}	23.52^{bc}	46.85^{c}	46.06^{c}	46.45^{c}
S2 (Blue net)	56.93^{c}	56.92^{bc}	56.92^{c}	23.18^{c}	23.15^{b}	23.16^{c}	46.63^{c}	45.60^{c}	46.12^{c}
S3 (yellow net)	59.55^{a}	59.61^{a}	59.58^{a}	24.71^{a}	24.56^{a}	24.63^{a}	50.27^{a}	49.20^{a}	49.73^{a}
S4 (White net)	58.38^{b}	58.26^{ab}	58.32^{b}	23.80^{b}	23.88^{ab}	23.84^{b}	48.01^{b}	46.97^{b}	47.49^{b}
S5 (Open field)	57.06^{c}	56.89^{bc}	56.98^{c}	23.73^{b}	23.70^{b}	23.71^{bc}	49.80^{a}	48.80^{a}	49.30^{a}
F-test	**	**	**	**	**	**	**	**	**
S.Em ±	0.16	0.24	0.19	0.07	0.11	0.08	0.12	0.11	0.11
CD @5%	0.52	0.77	0.63	0.21	0.35	0.27	0.40	0.35	0.36
Sub treatments (S)									
E0 (Distilled water)	57.17^{b}	57.11^{b}	57.14^{b}	23.87^{b}	23.87^{b}	23.87^{b}	50.01^{a}	47.10^{b}	48.55^{a}
E1 (Chitosan 1000 ppm)	55.64^{c}	55.67^{c}	55.66^{c}	22.06^{c}	22.04^{c}	22.05^{c}	44.89^{c}	45.34^{c}	45.11^{b}
E2 (SA 100 ppm)	58.59^{a}	58.51^{a}	58.55^{a}	23.67^{b}	23.60^{b}	23.63^{b}	49.67^{a}	48.67^{a}	49.17^{a}
E3 (Dry yeast 5000 ppm)	58.63^{a}	58.50^{a}	58.56^{a}	25.58^{a}	25.50^{a}	25.54^{a}	48.68^{b}	48.19^{a}	48.44^{a}
F-test	**	**	**	**	**	**	**	**	**
S.Em ±	0.12	0.12	0.12	0.06	0.09	0.07	0.11	0.12	0.11
CD @5%	0.36	0.35	0.34	0.18	0.27	0.21	0.32	0.34	0.32
Interaction (M x S)									
S1E0	52.45	52.52	52.48	23.20	23.37	23.28	43.43	41.26	42.35

S1E1	57.17	57.08	57.13	22.08	22.10	22.09	46.80	47.27	47.03
S1E2	55.62	55.47	55.54	23.40	23.20	23.30	48.75	47.78	48.26
S1E3	57.23	57.13	57.18	25.53	25.30	25.42	48.42	47.93	48.17
S2E0	58.87	58.67	58.77	25.03	24.83	24.93	52.17	49.04	50.60
S2E1	51.67	51.70	51.68	19.20	19.28	19.24	41.23	41.65	41.44
S2E2	58.13	58.37	58.25	22.53	22.50	22.52	46.15	45.23	45.69
S2E3	59.03	58.93	58.98	25.97	25.97	25.97	46.97	46.50	46.73
S3E0	59.03	59.28	59.16	25.00	24.97	24.98	52.43	49.29	50.86
S3E1	55.22	55.42	55.32	22.50	22.37	22.43	46.40	46.86	46.63
S3E2	62.92	62.75	62.83	24.45	24.30	24.38	55.20	54.10	54.65
S3E3	61.03	61.00	61.02	26.88	26.60	26.74	47.03	46.56	46.80
S4E0	57.38	57.22	57.30	23.50	23.52	23.51	51.73	48.63	50.18
S4E1	58.00	58.17	58.08	22.88	23.00	22.94	40.97	41.38	41.17
S4E2	59.25	59.08	59.17	23.68	23.62	23.65	48.95	47.97	48.46
S4E3	58.88	58.58	58.73	25.15	25.37	25.26	50.40	49.90	50.15
S5E0	58.10	57.87	57.98	22.63	22.68	22.66	50.28	47.27	48.77
S5E1	56.17	55.98	56.08	23.65	23.47	23.56	49.05	49.54	49.30
S5E2	57.02	56.87	56.94	24.27	24.37	24.32	49.28	48.30	48.79
S5E3	56.97	56.83	56.90	24.37	24.27	24.32	50.58	50.08	50.33
F-test	**	**	**	**	**	**	**	**	**
S.Em ±	0.28	0.27	0.26	0.14	0.21	0.16	0.25	0.26	0.25
CD @5%	0.80	0.78	0.75	0.39	0.60	0.47	0.71	0.75	0.71

- Significant at 1% *L-Lightness/brightness *a**- (+ *a** is red; -a* is green) # b*- (+*b** is yellow; -*b** is blue)

Plate 1: Samples showing highest (S3E2 write the treatment details for all) and lowest (S4E1) *b** values

Plate 2: Samples showing highest (S3E3) and lowest (S2E1) *a** values

Plate 3: Samples showing highest (S3E2) and lowest (S2E1) *L** values

Conclusion

Optimised growing environments by way of making provision for cultivating turmeric crop under photo-selective nets coupled with the application of a suitable metabolic elicitor may be considered as revealed in the present study to obtain turmeric powder of high quality with better consumer and industry preference. As per the results obtained in the present study, it is advisable to grow turmeric crop under yellow photo-selective net which provides 25 per cent shade to the crop and sprayed with salicylic acid at 100 PPM from one month to six months after planting at monthly interval to obtain turmeric powder with best colour values.

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