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Morphological and biochemical characterization of peel of different coloured mango cultivars

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Abstract
Some morphological and biochemical parameters were studied to characterize only mango fruit peel. Morphological evaluation of ripe fruits using mango descriptors revealed considerable variation amongst mango cultivars. Parameters 'L', 'b', 'C' and 'h' showed strong correlation with carotenoids in peel of different coloured cultivars. Also, Biochemical analysis showed a wide variation amongst different coloured mango cultivars with their changing pattern during ripening. The higher content of total chlorophyll, total carotenoids and anthocyanins were noticed in peel of green, yellow and red coloured cultivars respectively. The presence of small quantities of lycopene was also noticed in peel of these cultivars. Mango peel was found to be associated with a decrease in chlorophyll content and increase in the total carotenoids and total anthocyanin contents during ripening of fruit. This study reports some morphological and biochemical parameters of mango peel helpful in breeding (selection of parents) and processing (peel utilization) of fruits.

Keywords: Mango (*Mangifera indica* L.), peel morphology, peel colour, pigments, ripening

Introduction
Mango (*Mangifera indica* L.) is believed to be originated from Indo-Burman region and a wide diversity is available for the breeding of mango. Different coloured mangoes are available and accordingly have been generally categorized into three types *viz*. green, yellow and red.

Mango peel has been the commodity of interest among the researchers from various fields like human nutrition, biotechnology and pharmacy. Mango peel is a good source of other phyto-chemicals such as enzymes, vitamin E, vitamin C, cellulose, hemicellulose, lipids, protein and pectin [3, 5, 37]. The antioxidant properties of peel in terms of polyphenols, anthocyanins and carotenoids content implicated its potential utilization in nutraceutical and functional food industry [2, 3].

The varieties are developed from germplasm through selection on the basis of parameters like fruit shape, colour, size, flavour, aroma, taste, time of maturity, juice content, total soluble solids, acidity, *etc*. [36]. However, these traits are considered to be the most common and important characters for screening the cultivars that could be used in a selection, as well as those unsuitable could be discarded in breeding programs [26]. While selecting parents, preference has to be given for their proper identification through quantitative and qualitative characters. Information on availability of genetic diversity is a prerequisite for undertaking any breeding program [22, 34]. In fact, studying the genetic diversity amongst the conserved germplasm helps to understand the historical background of the elite cultivars that would serve as the backbone for traditional and non-traditional breeding programs [34]. Finally, this would help in selection of the elite parents and desirable progenies.

Assessing the biochemical composition of the mango peel in different varieties makes is it possible to select the variety for pharmaceuticals and breeding programs. The mango peel is a bio-waste and the knowledge of its biochemical constituents could substantiate its importance for crop production, processing and marketing of the fruits.

Pronounced inter-varietal composition differences would assist in selection of elite genotypes in future after evaluating their performances. The peel is considered as the major by-product of mango industry and knowing its composition would help in development of appropriate

utilization strategy. Keeping this in a view, present study was undertaken with the following objectives (i) To characterize morphological parameters of the ripe mango fruits of different coloured cultivars and (ii) To measure colours and different biochemical parameters of peel of coloured mango cultivars during ripening.

Materials and Methods

Some of the coloured cultivars available in Mango Field Gene Bank of ICAR-Indian Institute of Horticultural Research, Bengaluru were selected for the present study. Fruits of mango cultivars belonging to three coloured groups *viz*., green (Langra, Amrapali, Hamlet and Bombay No.1), yellow (Arka Anmol, Lazzat Baksh, Peach and Banganapalli) and red (Tommy Atkins, Lalmuni, Gulabi, Janardhan Pasand, Lily and Ostin) were tagged at 50 per cent flowering stage and subsequently fruits were harvested at two dates on the basis of visual maturity indices and previous year data. The first harvest was carried out at 80% maturity (S1) and second at 100% (S2) maturity). For ripened stage (S3), fruits were harvested at 100% maturity and kept for normal ripening after washing with water. Hence, the sampling was done at three stages *viz*., 80%, 100% and ripe stages. Fruits (at least twenty replications at each stage) were subjected for the morphological and colour evaluation before storing peel samples for biochemical analysis. For, biochemical part of the work, fruits were washed, peeled with sterilized peeler, separated from adhering pulp, frozen in liquid Nitrogen and stored at -80^{0}C until analysis.

Fruit characterization for the mango fruits of different cultivars was carried out using the universally accepted standard mango descriptor [13]. The peel colours in terms of 'L', 'a', 'b', 'C' and 'h' scales at both sides of the fruits were recorded using a colour reader, CR-10 (Minolta Co., Ltd, Osaka, Japan).

The total chlorophyll, carotenoids and lycopene were analyzed by following the spectrophotometric method of Lichtenthaler (1987) [21]. Peel sample (5g) was ground completely with acetone until clear extract and the known volume was made up. The extract was dehydrated using anhydrous Na_2SO_4 (Sodium Sulphate). The absorbance of the extract was read at 660 nm and 642 nm. Total chlorophyll contents were then calculated by using the standard value and expressed as µg/100g. Extracted samples used in chlorophyll estimation were carried forward for the total carotenoids and total lycopene estimation. To remove the chlorophylls and unwanted lipids completely, saponification was done with 10% KOH. The non-aqueous layer was separated and the absorbance was read at 450 nm for total carotenoids and at 503 nm for lycopene using spectrophotometer. The standard curve was plotted through serial dilution for standard β-carotene and lycopene (Sigma Chem. Co., USA) and total carotenoids and total lycopene contents were calculated in terms of mg/100gFW.

Estimation of anthocyanins was carried out following method of Shivashankara *et al.* (2010) [35]. Using pestle and mortar, peel samples were ground and clear extract was collected, and finally volume was made up to the known volume and absorption was read at 540 nm using Spectrophotometer. All extractions were carried out at low light to avoid degradation of the anthocyanins. The standard curve was plotted through serial dilution for standard cyaniding and total anthocyanin was calculated and expressed in terms of mg/100g FW.

The total flavonoids in mango peel were measured by method of Chun *et al.* (2003) [9]. Peel samples were ground with 80% methanol in a pestle and mortar and made up the volume to the known volume. Solution was added with $AlCl_3$ and potassium acetate followed by incubation and total flavonoids were estimated by reading the absorbance at 510 nm calculated using the standard value of catechin expressed in terms of mg/100g.

Titration method was followed for determining tiratable acidity in terms of per cent citric acid [31]. Five gram of peel sample was ground with distilled water, filtered through muslin cloth and volume was made upto known volume. A Peel extract was titrated against 0.01N NaOH using phenolphthalein as indicator and titratable acidity (% citric acid) was calculated.

Results were subjected for ANOVA (analysis of variance) under completely randomized design (CRD) at 1% probability using AGRES software version 3.01 (Pascal International Software Solutions, USA). Pearson's correlation coefficients (r) and p-value were calculated using MS-Excel and online available statistical calculator (http://www.danielsoper.com/statcalc3/) for correlation interpretation between pigments (carotenoids and anthocyanins) and colour values.

Results and Discussion

Morphological characterization of ripe fruits of different mango cultivars

Fourteen mango cultivars belonging to different peel colour categories green, yellow and red revealed considerable variations for 25 fruit descriptors (Table 1). The duration of fruit maturity was long in 'Amrapali' (140 to 154 days) followed by 'Tommy Atkins' (142-150 days), whereas, the shortest duration was observed in cultivars 'Lazzat Baksh' (95 to 123). Hence, as per this study, duration of fruiting in mango vary from 95 to 154 days after fruit set. Similar findings have also been reported by Kalra *et al.* (1995) in some other cultivars of mango.

Table 1: Descriptors of colored mango cultivars

Sr. No.	Fruit descriptors	LAN	AMP	HAM	B N.1	AA	LZB	PEA	BGNP	TAM	LAL	GUL	JPM	LIL	OST
1	Fruiting duration (days from fruit set)	103-110	140-154	108-128	119-123	124-135	95-123	110-125	130-145	142-150	112-120	128-130	130-143	125-135	132-142
2	Fruit bearing intensity	High	High	High	High	High	High	High	High	High	High	High	High	High	High
3	Fruit length (cm)	9.65±0.84	9.58±0.82	12.2±0.7	8.32±0.36	10.1±0.35	8.70±0.20	7.8±0.24	12.5±0.33	10.38±0.6	7.98±0.28	12.4±0.72	10.0±0.6	10.6±0.8	11.7±0.4
4	Fruit diameter (cm)	6.97±0.41	5.57±0.32	9.02±0.69	7.01±0.60	7.34±0.57	5.36±0.21	6.63±0.48	8.87±0.53	9.3±0.48	5.5±0.29	8.4±0.49	6.2±0.66	8.2±0.4	8.2±0.4
5	Fruit weight (g)	216.64±29.39	135.94±12.33	406.44±94.52	309.42±76.87	240.34±5.2	125.79±11.5	162.4±20	509±12.3	419±35.5	126±12.4	419.64±33.	234.80±7.9	377±41.6	414.9±35
6	Fruit shape	Elliptic	Oblong	Oblong	Roundish	Oblong	Obtuse	Roundish	Roundish	Round	Oblong	Elliptic	Obovoid	Ovoid	Oblong
7	Shape of fruit apex	Round	Acute	Obtuse	Obtuse	Obtuse	Acute	Acute	Acute	Obtuse	Acute	Obtuse	Acute	Round	Acute
8	Fruit attractiveness	Poor	Poor	Poor	Poor	Excellent	Average	Excellent	Excellent	Excellent	Good	Good	Excellent	Excellent	Good
9	Skin color of ripe fruit	Green	Green	Green	Green	Yellow	Yellow	Other	Yellow	Red	Purple	Red	Red	Red	Grey
9a	Fruit ground color	Green	Green	Green	Green	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green
9b	Fruit blush	Other	Other	Other	Other	Other	Other	Orange	other	Purple	Purple	Red	Red	Red	Purple
10	Fruit skin thickness (mm)	2.10±0.06	0.86±0.05	1.54±0.21	1.13±0.007	1.16±0.05	1.11±0.37	1.04±0.04	0.77±0.30	1.32±0.122	1.36±0.05	1.94±0.27	0.62±0.11	1.11±13	0.80±0.12
11	Fruit skin surface texture	Smooth	Smooth	Smooth	Rough	Smooth	Rough	Smooth	Smooth	Smooth	Smooth	Rough	Smooth	Smooth	Smooth
12	Density of lenticels on fruit skin	Sparse	Medium	Sparse	Medium	Sparse	Medium	Dense	Medium	Sparse	Medium	Intermediate	Dense	Dense	Sparse
13	Fruit stalk insertion	Oblique	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Oblique	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical
14	Depth of fruit stalk cavity	Absent	Absent	Absent	Shallow	Absent	Absent	Absent	Medium	Shallow	Absent	Shallow	Absent	Shallow	Absent
15	Fruit stalk attachment	Weak	Weak	Intermediate	Strong	Weak	Intermediate	Intermediate	Weak	Strong	Weak	Weak	Intermediate	Weak	Weak
16	Fruit neck prominence	Slghtly prominent	Prominent	Prominent	Slightly prominent	Slighly prominent	Absent	Prominent	Absent	Slightly prominent	Absent	Absent	Very prominent	Slighlty prominent	Slighlty prominent
17	Slope of fruit ventral shoulder	Ending in long curve	Sloping abruptly	Ending in long curve	Ending in long curve	Ending in long curve	Sloping abruptly	Ending in long curve	Ending in long curve	Rising and then rounded	Ending in long curve	Sloping abruptly	Slopping abruptly	Ending in long curve	Sloping abruptly
18	Fruit beak type	Perceptile	Pointed	Perceptile	Perceptile	Pointed	Prominent	Perceptile	Perceptile	Mammiform	Pointed	Perceptile	Pointed	Perceptile	Pointed
19	Fruit sinus type	Absent	Shallow	Absent	Shallow	Shallow	Absent	Shallow	Shallow	Shallow	Absent	Absent	Absent	Absent	Absent
20	Fruit skin waxiness	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy	Waxy
21	Skin color of ripe fruit	Green	Green	Green	Green	Yellow	Yellow	Yellow	Yellow	Red	Green with red blush	Green with red blush	Green with red blush	Red	Green with purple patches
22	Pulp color of ripe fruit	Golden yellow	Yellow orange	Yellow orange	Yellow	Yellow orange	Golden yellow	Golden yellow	Yellow	Yellow	Gloden yellow	Yellow	Light yellow	Yellow	Orange
23	Pulp texture of ripe fruit	Intermediate	Intermediate	Soft	Intermediate	Inetermediate	Firm	Intermediate	Intermediate	Firm	Intermediate	Firm	Intermediate	Intermediate	Firm
24	Adherence of fruit skin to pulp	Intermediate	Free	Firm	Intermediate	Free	Free	Intermediate	Strong	Intermediate	Firm	Strong	Intermediate	Strong	Inetermediate
25	Quantity of latex oozing from peduncle	High	Low	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	High	High	Medium	Low

The values are mean±standard error of 20 replicates. Codes of different cultivars are: LAN (‘Langra’), AMP (‘Amrapali’), HAM (‘Hamlet’), BN1 (‘Bombay No. 1’), AA (‘Arka Anmol’), LZB (‘Lazzat Baksh’), PEA (‘Peach’), BGNP (‘Banganapalli’), TAM (‘Tommy Atkins’), LAL (‘Lalmuni’), GUL (‘Gulabi’), JPM (‘Janardhan Pasand’), OST (‘Ostin’) and (‘Lily’).

Table 2: Various color parameters evaluated by Minolta colorimeter for peel colors of different colored cultivars of mango at fully ripe stage.

Cultivar	'L'	'a'	'b'	'C'	'h'
Langra	52.54± 2.14bc	-10.40±0.67f	27.22±2.65cde	31.66±3.11ef	108.66±4.12a
Amrapali*	50.36±2.59bcd	-8.66±2.55f	28.60±5.30bcd	29.50±4.82def	108.32±8.60a
Hamlet	53.86±1.89b	-13.02±2.00f	34.54±2.45b	36.12±2.77e	111.08±2.94a
Bombay No. 1	50.20±1.47efg	-10.40±0.71f	25.30±0.51ef	29.99±3.22g	106.30±5.46a
Arka Anmol*	62.86±3.55a	13.46±1.33c	48.86±3.78a	51.18±1.67a	74.32±2.67b
Lazzat Baksh	63.72±3.87a	10.54±3.26cd	43.24±3.37a	43.12±1.32b	76.00±4.17b
Peach	61.58±3.46a	10.56±2.62cd	46.74±3.99a	49.08±5.86ab	77.30±3.58b
Banganapalli	66.00±2.27a	6.20±2.99de	48.98±5.48a	49.32±3.71ab	84.02±2.40b
Tommy Atkins	46.04±4.3def	13.60±5.79a	29.36±4.40bcd	27.26±6.492cd	51.08±15.41cd
Lalmuni	44.10±5.73def	33.96±5.23ab	20.48±12.09bc	39.20±4.19fg	31.94±13.11c
Gulabi	42.28±4.79ef	20.26±12.51a	21.88±6.93ef	31.80±13.16cd	38.68±9.04e
Janardhan Pasand*	45.76±7.85fg	29.92±4.97b	28.12±8.02def	39.34±5.40ef	50.20±12.37de
Ostin	38.98±2.13g	30.96±2.78a	15.46±1.93f	35.20de	31.00±4.01e
Lily	43.60±3.74cde	12.80±10e	19.53±7.56cde	24.50ef	57.09±20.48b
SEd	2.49	3.33	3.59	3.37	5.95
CD (p<0.01)	6.64	8.90	9.59	8.99	15.96

*Some data of three varieties *viz*. Amrapali, Arka Anmol and Janardhan Pasand have been published by Karanjalker *et al*. (2017) [15]. Analysis was carried out with at least 20 replications, SEd: Standard Error deviation, CD: critical difference at *P*<0.01% s

The significant variation for the fruit size could be noticed in terms of length and diameter of the fruits of different cultivars. The highest length was observed in case of 'Banganapalli' (12.57±0.33 cm), 'Gulabi' (12.40±0.72 cm), 'Hamlet' (12.22±0.7 cm) and 'Ostin' (11.78±0.4 cm) and the least was in 'Peach' (7.8±0.24cm). However, highest diameter at the broader sides was observed in 'Tommy Atkins' (9.30±0.48 cm), 'Hamlet' (9.02±0.69 cm) and 'Banganapalli' (8.87±0.53 cm) and lowest in 'Lazzat Baksh' (5.36±0.21 cm). The significant variation in length and diameter of the fruits among cultivars like 'Tommy Atkins' also indicated distinct shapes of elliptic, oblong, obtuse, roundish, obovoid, oblong and ovoid natures of mango fruits. The bigger sized and heavier fruits were observed in cultivars 'Hamlet', 'Gulabi', 'Tommy Atkins', 'Ostin', Lily, 'Langra', 'Banganapalli' and 'Bombay No.1'. In contrary, cultivars 'Peach', 'Lazzat Baksh', 'Amrapali' possessed smaller sized fruits, whereas, medium sized was observed in 'Arka Anmol' and 'Janardhan Pasand'.

A wide variation for different descriptors *viz*. fruit length (ranged from 7.8 to 12.57 cm), fruit diameter (5.36 to 9.30 cm), fruit weight (125.79 to 509.58 g), fruit shape (elliptic to roundish), apex shape (acute to round), density of lenticels on fruit skin (sparse to dense), stalk insertion (oblique to vertical), stalk depth (absent to shallow), beak types (pointed to perceptile), sinus types (absent to shallow), skin thickness (0.62 to 2.10 mm) and adherence of skin to pulp (firm to strong) was observed amongst cultivars (Table 1). The presence of waxiness was also noticed on the peel of all cultivars. Variations for these parameters were also reported by researchers [32].

In general, fruit weight (125.79 to 509.58 g) and fruit length (7.8 to 12.57 cm) observed in the present study (Table 1) is similar to the values recorded by Singh *et al.* (2012) [36] where it varied from 50.3 to 380.4 g for fruit weight and 6.03 to 12.52 cm for fruit length amongst 28 unexploited mango varieties. A wide variability has been reported for fruit weight and size in different mango cultivars in India [14, 22]. Similarly, considerable diversity has been reported for Mexican mangoes for fruit traits *viz*. length, width, weight, *etc.* [12].

The other parameters like fruit shapes (elliptic to round), apex shape (acute to round), density of lenticels on fruit skin (sparse to dense), fruit stalk insertion (oblique and vertical), depth of fruit stalk cavity (absent to shallow), fruit beak type (pointed to perceptile) and fruit sinus type (absent to shallow) explains the presence of a wide diversity among mango genotypes (Table 1). The peel thickness varied from 0.62 to 2.10 mm amongst the cultivars studied here. Pulp adherence to the peel (skin) varied from free to strong among cultivars at ripe stage. In majority of cultivars, pulp colour was observed to be golden yellow. The texture of pulp varied from soft to firm. Also, sap ooziness varied from low to high within the cultivars. These descriptors presented shows significant features of ripe mango fruits of different coloured cultivars of mango.

Regarding colour, apart from typical green, yellow and red colours, blushes of these types were also observed (Table 1). In cultivars 'Gulabi', 'Janardhan Pasand' and 'Lily', red blushes were present on the shoulders of ripe fruits. However, purple blushes were observed in case of 'Tommy Atkins', 'Lalmuni' and 'Ostin' fruits. Fruit of cultivar 'Peach' were of yellow ground colour with orange blushes. In the present investigation, fourteen cultivars belonging to three coloured peel categories (green, yellow and red) were observed to have yellow, yellowish red or orange-red blush on the peel, especially on shoulders and tips. Some of the cultivars were recorded with green ground colours as well. Many of researchers like Singh *et al. (*2012), Begum *et al.* (2012) and Dinesh *et al. (*2012) [6, 10, 36] have made significant contributions in improving our understanding on this aspect. They mainly reported the presence of yellow, greenish yellow, reddish yellow, yellow orange, reddish as well as blushed natures of mango peel colours. The peel colour varied from yellow to reddish yellow amongst accession of Andhra Pradesh [6].

Morphological characterization is a prerequisite for observing diversity, germplasm conservation and utilization in breeding programmes [6]. Considering the variability observed during the present investigation, for various morphological traits among the mango cultivars from earlier reports, the diversity could be utilized for processing and crop improvement programmes.

Mango peel colours at different ripening stages

The lightness ('L') depicts the higher values (100) towards whiteness and lower (0) values towards blackishness. Among the different coloured cultivars evaluated at ripe stage, highest lightness (L) was observed in 'Banganapalli' (66.00) that was on par with 'Lazzat Baksh' (63.72), 'Arka Anmol' (62.86) and 'Peach' (61.58) (Table 2). These cultivars are yellow

coloured. However, low values of 'L' were recorded in case of red coloured cultivars. Hence, lightness was more in yellow followed by green and red coloured mango peel. Retention in 'L' values was evident in mango peel during ripening in case of the green and red coloured cultivars (Fig. 1a). However, in yellow coloured cultivars, the lightness increased during ripening process.

The hunter 'a' value explains the contrasting redness (positive values) and greenness (negative values) for the test commodity. All yellow and red coloured cultivars at ripe stage showed positive values and contrast in case of the green coloured cultivars (Table 2). The highest 'a' values were observed in red coloured 'Lalmuni' (33.96) and 'Ostin' (30.96). The least and negative values were observed in case of green coloured cultivars (-8.66 to -13.02) indicating their colour retention. In red coloured cultivars, the drastic increase in 'a' value was observed during ripening (Fig. 1b). Also the increase in 'a' values was observed in case of yellow cultivars that changed significantly from negative to positive values during ripening. This suggests their changing colours from green. But in green coloured cultivars, negative values were retained during the ripening of fruits indicating their retention of green colour.

The 'b' values withstand for the critical views on the contrasting yellow (positive values) and blue (negative values) of colours. Significant higher values for yellow were observed in yellow coloured cultivars that ranged from 43.24 (*cv*. Lazzat Baksh) to 48.98 (*cv*. Banganapalli) (Table 2), whereas, the least values were obtained for red coloured 'Lily' (15.46). Generally, 'b' values were higher in yellow coloured followed by green and red coloured varieties. During ripening of the fruits, drastic increase in the values of 'b' by 20 folds from the mature stage was observed in yellow colour indicating development of yellow colour during ripening (Fig. 1c). However, values of 'b' either remained unchanged or decreased during ripening in other coloured cultivars.

Chroma values explain the intensity or purity of dominant colours. The 'c' values were significantly higher in case of the yellow coloured cultivar that indicated their purity of yellow colour (Table 2). The 'c' values were significantly higher in case of the yellow coloured cultivar that indicated their purity of yellow colour (Table 2). The highest value for chroma (c) was noticed in yellow coloured *cv*. 'Arka Anmol' (51.18) and significantly lower 'c' value was noticed in red coloured *cv*. 'Tommy Atkins' (27.26). No significant variation among the red and green colours indicates that there are mixture of the other colours. Increased 'c' values were evident in yellow coloured cultivars during ripening, whereas the constant expression was observed in other types of the colours (Fig. 1d).

Hue angle indicates the dominant colours of the test commodity implicated through values of 0º as red, 90 º as yellow, 180 º as green and 270 º as blue colours. The higher 'h' values were observed for green coloured cultivars ('Langra','Amrapali', 'Hamlet' and 'Bombay No.1') followed by yellow and red types (Table 2). The highest hue angle was observed for the green coloured 'Hamlet' (111.08) and least in red coloured 'Ostin' (31.0) indicating their respective dominant green and red colour. At initial maturity stages (80% and 100% maturity) in yellow coloured cultivars the higher values were obtained showing its green nature, however later showed decrease during ripening at ripe stage. Hence, decrease in 'h' values was noticed in yellow and red coloured cultivars. However, almost constant values of 'h' were recorded in green cultivars (Fig. 1e).

The values obtained in the present study were similar with the values observed for 'L', 'a', 'b', 'c' and 'h' by Nambi *et al.* (2015) [28] for two yellow coloured cultivars *viz.* 'Alphonso' and 'Banganapalli'. Ayala-Silva *et al.* (2005) [4] reported colour parameters for different coloured mango cultivars 'Keitt', 'Mamita', 'Sandersha', 'Tommy Atkins', 'Tyler Premier' and 'White Alfonso'. Similar studies on colour evaluation were also undertaken in mango by Ornelas-Paz *et al.* (2008) [30] where they observed values for 'L' (47.3±1.4 to 71.4±0.6), 'a' (9.8±1.5 to 23.6±1.3),' b' (21.0±2.4 to 43.8±0.4), 'C' (29.14±1.0 to 47.4±0.3) and 'h' (39.6±4.1 to 74.0±0.3). Also, Muengkaew *et al.* (2016) [27] observed 38.37, 3.37, 26.75 and 82.81 values for 'L', 'a', 'b' and 'h' respectively for mango peel of red coloured *cv*. 'Manhachanok'.

For the 14 cultivars used in the present study, colour parameters showed differential values during ripening (Table 2). Such developmental pattern was also observed in the cherry [7]. The peel colour is an important quality parameter of fruit that appeals to consumer, helps to predict maturity and internal quality [4]. In the present study, the colours were evaluated in order to characterize peel of different coloured cultivars using colourimeter. Results revealed significant variations among different groups (green, yellow and red types) studied. The colour variation was also observed within the groups and at different stages of maturity.

Correlation between colour and pigments of mango peel at ripe stage

Correlation between colour parameters (L, a, b, C, h) and pigments (carotenoids and anthocyanins) of mango peel were worked out to further elaborate our results. Parameter 'a' (r=0.738) showed high positive correlation with anthocyain contents, while for 'L' and 'C' it was negative (Table 3). The 'b' represents colour in terms of positive values for red and negative values for green colours. In red coloured cultivars 'Tommy Atkins', 'Lalmuni', 'Gulabi' and 'Janardhan Pasand 'positive 'a' values were observed and hence might have showed the positive correlation with anthocyanin contents in mango peel. The hue angle distribution amongst the cultivars was used to illustrate the peel colour and its correlation with anthocyanin and chlorophyll contents [29]. The red coloured cultivars showed positive correlation (0.76≥r≥0.58) for hue angle and anthocyanin contents. Kasim *et al.* (2011) [17] evaluated 12 cultivars of cherry laurel (*Prunus laurocerasus* L.) fruits for colours and anthocyanins suggested that there were strong correlation of anthocyanins with chromatic parameters (a* b*, chroma, and hue angle) except for L* value.

Table 3: Pearson's correlation (r) between pigments (carotenoids and anthocyanin) with color values at ripen stage

Color Parameters	Anthocyanin Contents		carotenoid contents	
	r-value	significance	r-value	significance
'L'	-0.500	0.08	0.758	0.008**
'a'	0.738	0.011*	0.200	0.302
'b'	0.0412	0.458	0.664	0.025*
'C'	-0.0028	0.497	0.797	0.005**
'h'	0.041	0.458	0.664	0.025*

The correlation values range from -1 to 1. Asterisk symbol (*) represents the significance of r values *p≤0.05, **p≤ 0.01 and ***p≤ 0.001

Regarding correlation of colour parameters and carotenoids, there was a positive correlation for all the parameters 'L'

(r=0.75; p<0.008), 'a' (r=0.200; p<0.302), 'b' (r=0.664; p<0.025), 'c' (r=0.797; p<0.005) and 'h' (r=0.664; p<0.025) (Table 3). Moreover, the 'L' (r=0.758; p<0.008) and 'C' (r=0.797; p<0.005) showed to be highly correlated with the carotenoids. These parameters explain the yellowness of cultivars *viz*. 'Arka Anmol', 'Lazzat Baksh', 'Peach' and 'Banganapalli' that was observed with high caroetenoids. Hence the positive correlation showed its nature of colours and direct correlation with carotenoids. Ornelas-Paz *et al.*, (2008)[30] correlated various colour parameters 'L' (47.3±1.4 to 71.4±0.6), 'a' (9.8±1.5 to 23.6±1.3), 'b' (21.0±2.4 to 43.8±0.4), 'c' (29.14±1.0 to 47.4±0.3) and 'h' (39.6±4.1 to 74.0±0.3) which was positively correlated with carotenoid contents of yellow coloured cultivars.

Biochemical analysis of peel of different coloured mango cultivars at ripening stages

Comparison of total chlorophyll contents in ripe peel of coloured mango cultivars showed significant variation (Table 4). Highest total chlorophyll contents were recorded in peel of green coloured cultivars 'Bombay No. 1' (26.73 µg /100g FW) 'Amrapali' (13.96 µg/100g FW), 'Langra' (10.76 µg/100g FW) and 'Hamlet' (10.27 µg/100g FW) and lowest was recorded in red coloured cultivar 'Lily' (0.60 µg/100g FW). The high chlorophyll content (26.73 µg/100g FW) was observed in green coloured 'Bombay No. 1' and moderate contents was in yellow coloured 'Banganapalli' (13.30 µg/100g FW) and red coloured 'Lalmuni' (9.60 µg/100g FW) which was *on* par with two green coloured cultivars ('Langra' and 'Amrapali'). However, lower concentration was observed in red coloured 'Lily' (0.64 µg/100g FW) and 'Ostin' (2.42 µg/100g FW) peel. Generally, chlorophyll contents in mango peel were high in green coloured cultivars at ripe stages and varied from 0.67 µg/100g FW (red coloured *cv*. Lily) to 26.73 µg/100g FW (green coloured *cv*. Bombay No.1) are in agreement with those reported by earlier investigators [3, 19, 30, 39].

The loss of total chlorophyll content was observed in peel during ripening of fruits in coloured cultivars (Fig. 2a). A gradual degradation of total chlorophyll content from 2.5 to 0.8 µg/100g FW from unripe to ripe stage was also observed by Medlicott *et al.* (1986) [25] in red coloured *cv*. 'Tommy Atkins'. In the present study, the green coloured mango cultivars were having higher chlorophyll content. The degradation of total chlorophyll contents was observed during ripening indicating its role in imparting peel colour (Fig. 2a).

The significant difference for total carotenoids was observed amongst the peel of different coloured cultivars (Table 4). The yellow coloured cultivar 'Arka Anmol' was observed with highest total carotenoids (54.6 mg/100g FW) and lowest in red coloured 'Lily' (2.3 mg/100g FW). Except for cultivar 'Banganapalli', all other yellow coloured cultivars were superior to other ones for total carotenoids. Yellow coloured 'Banganapalli' which was expected to posess high carotenoids contents because of its yellow colour was observed with moderate carotenoids (12.5 mg/100g FW) which was *on-par* with some of the red and green coloured cultivars. Total carotenoids were also higher in cultivar 'Amrapali' (green) (24.1 mg/100g FW) even though it is green in colour. Generally, total carotenoids in mango peel were higher in yellow coloured cultivar and it ranged from 2.3 mg/100g FW (red coloured *cv*. Lily) to 54.6 mg/100g FW (yellow coloured *cv*. Arka Anmol).

Total carotenoid content varied from 23 to 546 µg/g on fresh weight basis amongst the cultivars studied here (Table 4). This finding is in accordance with the earlier reports by Ajila *et al.* (2007) [2] and Nordey *et al.* (2014) [29] and who suggested that total carotenoids in mango peel extracts vary between *i.e.*, 14.37 to 35.9 µg/g FW and 74 to 436 µg/g FW, respectively. However, another report by the same group of researchers [3] suggested that total carotenoid contents vary between 1400 µg/g ('Badami') and 3945 µg/g FW ('Raspuri') among yellow coloured mango cultivars. Similarly, Rymbai *et al.* (2013) [33] reported high variations for total carotenoids (493 to 3,945 µg/g FW) in peel of mango. This variation in contents might be due to saponification step that removes some of the carotenoids and other impurities [8]. Saponification was carried out during the present study in order to obtain pure carotenoids and hence it could possibly be the.

Table 4: Various biochemical characters of mango peel of different colored cultivars at fully ripe stage.

Sr. No	Cultivar	Peel color	Total chlorophyll (µg/100g FW)*	Total carotenoids (mg/100g FW)*	Total lycopene (mg/100g FW)	Total anthocyanin (mg/100g FW)*	Total flavonoids (mg/100g FW)	Titratable acidity (% C.A)
1	Langra	Green	10.76±2.35c	18.7±1.3f	0.15±0.019ef	3.14±0.33b	19.70±98.19c	1.39a
2	Amrapali	Green	13.96±4.78b	24.1±6.2cde	0.27±0.04bc	5.68±0.16ef	41.06±2.64a	1.28a
3	Hamlet	Green	10.27±1.14c	10.8±2.9fh	0.15±0.024efg	1.24±0.28h	8.32±2.50ef	1.28a
4	Bombay No. 1	Green	26.73±0.29a	25.8±2.6cd	0.40±0.0033b	7.80±3.42de	9.50±0.73ef	1.17ab
5	Arka Anmol	Yellow	3.13±0.19efg	54.6±5.0a	0.78±0.018a	6.70±0.26ef	10.57±0.68def	1.17ab
6	Lazzat Baksh	Yellow	2.89±0.20efg	28.5±2.08bc	0.27±0.115bcd	1.85±0.29h	11.24±0.56def	1.28a
7	Peach	Yellow	6.30±1.14def	37.8±0.188b	0.36±0.008b	2.41±0.31h	7.44±0.41ef	1.28a
8	Banganapalli	Yellow	13.30±0.471cd	12.5±0.4fg	0.19±0.0057cde	4.94±0.94f	5.13±0.11f	0.75cd
9	Tommy Atkins	Red	3.29±0.90efg	20.9±0.96cde	0.07±0.069fgh	13.08±0.81b	13.82±0.59cde	0.85cd
10	Lalmuni	Red	4.88±1.19def	22.91±0.14cde	0.09±0.092efg	12.91±3.50b	12.93±1.55de	0.96bc
11	Gulabi	Red	9.60±1.85cde	8.65±2.5gh	0.03±0.035hi	10.77±0.23bc	16.66±0.215cd	0.96bc
12	Janardhan Pasand	Red	3.12±0.31efg	16.2±2.5def	0.16±0.0051def	21.25±1.07a	28.08±10.98b	1.28a
13	Ostin	Red	2.42±0.24g	16.1±0.52def	0.04±0.041ghi	9.35±0.036cd	10.93±0.87de	0.96bc
14	Lily	Red	0.64±0.131fg	2.3±0.1h	0.05±0.046i	21.74±1.16a	11.98±0.54def	0.64d
	SEd		3.42	0.532	0.05	0.21	3.26	0.11
	CD (p<0.01)		9.02	14.7	0.14	3.36	9.01	0.31

Some data for total Chlorophyll, carotenoids and anthocyanins has been published by Karanjalker *et al*. (2018) [16] as supplementary file with different objective. Values are mean±standard error of triplicate analysis, SEd: Standard Error deviation, CD: critical difference at p<0.01%, *Significance. Titratable acidity was expressed in terms of per cent citric acid (% C.A).

reason for lower concentration observed during the present study. One of the yellow coloured *cv*. 'Banganapalli' was having moderate (12.5 mg/100g FW) carotenoid contents (Table 4). However, this cultivar was observed with high chlorophyll contents at the fully ripe stage. Another noticeable fact, that green coloured *cv*. 'Amrapali' was recorded with moderate total carotenoid content (24.1 mg/100g FW) and high chlorophyll content (0.013 mg/100g FW) (Table 4). This indicates the combined action of different pigments for their respective final colours.

During ripening, increase in the carotenoid contents were observed (Fig. 2b) for all coloured cultivars. Drastic rise in total carotenoids from mature (11.46 mg/100 FW) to fully ripe (54.55 mg/100g FW) stage was noticed in 'Arka Anmol' peel. However, a minimum of two fold increase in carotenoids contents were observed in other cultivars during ripening. Higher carotenoids contents were recorded in yellow coloured cultivars which increased drastically during ripening. The increase in total carotenoids by five folds along with the degradation of chlorophylls and anthocyanins was observed in 'Tommy Atkins' mango peel [25]. The similar trend was also observed in the present study. Hence, total carotenoid content in peel of different coloured mango cultivars were characterized and it was higher in yellow coloured cultivars. Also the drastic increase in their contents during ripening indicated their major role in development of yellow colours during ripening.

Similar to total carotenoid contents, significant variation amongst different coloured cultivars were observed for lycopene content (Table 4), wherein, highest lycopene was observed for 'Arka Anmol' (0.78 mg/100g FW) peel. The total lycopene contents in peels of different coloured cultivars varied from 0.03 to 0.78 mg/100g FW. The yellow coloured cultivars registered for higher lycopene contents. During ripening, drastic increase was observed for total lycopene in all coloured cultivars (Fig. 2c). Similar to total carotenoids, lycopene was synthesized at higher levels in the yellow coloured cultivars that might have contributed to the colouration of peel. The total lycopene contents were higher in yellow coloured cultivars and the present study reports its content in peel of different coloured mango cultivars. Lycopene is even known for its role as antioxidant.

The highest total anthocyanin contents were observed in 'Lily' (21.74 mg/100g FW) which was on par with 'Janardhan Pasand' (21.25 mg/100g FW) and significantly lowest in green coloured 'Hamlet' (1.24 mg/100 FW) (Table 4). The higher anthocyanin contents in peel of yellow *cv*. 'Arka Anmol' (6.70 mg/100g FW) and green *cv*. 'Bombay No. 1 (7.80 mg/100g FW), showed close values with some red coloured *cv*. 'Ostin' (9.35 mg/100g FW). Generally, total anthocyanin contents were significantly higher in red coloured cultivars than other groups (Table 4). Anthocyanins are responsible for red, blue and purple colours [18]. Comparison of their contents at fully ripe fruit stage, amongst different coloured cultivars showed its significantly higher content in red cultivars. Muengkaew *et al.* (2016) [27] reported total anthocyanin contents of 1.22 mg/100g FW in ripe mangoes of red coloured *cv*. 'Mahachanok', while Dorta *et al.* (2012) [11] reported total anthocyanin content of 0.5 to 1.9 mg/100g DW. These reports showed some resemblance with values obtained in the present study (1.24 to 21.74 mg/100g FW). On the contrary, Ajila *et al* (2007a) [3] reported considerably higher amounts of total anthocyanin in raw (203 to 326 mg/100g FW) and ripe peel (360 to 565 mg/100 g FW) of 'Badami' and 'Raspuri' mangoes.

Significant increase in total anthocyanin contents was noticed in peel of red coloured cultivars (Fig. 2d). However, irregular pattern of either reduction or no significant variation during ripening was evident in other coloured cultivars (green and yellow) except in case of yellow orange coloured cultivar 'Arka Anmol' that showed significant increase from mature (2.54 mg/100g FW) to fully ripe (6.70 mg/100g FW). Total anthocyanin contents were higher in all red coloured cultivars than other coloured types and content significantly increased during ripening. However, in some cultivars it did not differ during ripening (Fig. 2d). The pattern of anthocyanins during ripening was studied by Medlicott *et al.* (1986) [25], showed slight reduction of total anthocyanin contents in red coloured *var*. 'Tommy Atkins'. However, significant increase was observed in the same cultivar in this study. Though significant reduction was observed in some cultivars *viz*., 'Langra', 'Hamlet' and 'Lazzat Baksh', however the retention of anthocyanins was noticed during the present study. The high content of the total anthocyanins in peel of red coloured cultivars that increased drastically during ripening suggest its role in red colour development.

In the present study, higher anthocyanin content recorded in ripe peel of red coloured cultivars suggested, the role of the anthocyanins in red colouration of peel in mango cultivars. Also a higher content of anthocyanins in yellow orange coloured 'Arka Anmol' suggested the combined action of anthocyanin and carotenoids for its yellow orange colours. Higher anthocyanin content in peel is also of a great value for processing industry as they are important antioxidants beneficial for human health.

The total flavonoid content, evaluated in mango peel at fully ripe stage showed a great variation amongst different coloured cultivars (Table 4). The flavonoids were significantly higher in *cv*. 'Amrapali'. However, no clear pattern could be suggested for flavonoids content as per the classification of mango fruits according to their colours. Total flavonoids content varied between 5.13 and 41.06 mg/100g FW among the cultivars studied and its content remained constant during the ripening stage, except for 'Amrapali' and 'Janardhan Pasand' (Fig. 1e). Total flavonoid contents were previously reported [13] to be 22.16 and 21.16 mg/g DW in unripe and ripe peel, respectively, where there was no significant change during ripening. Also Umamahesh *et al.* (2016) [38] found flavonoid content vary from 8.7 to 15.6 mg/g DW in mango peel.

Flavonoids are important biochemical with nutraceutical property, which are essential for human health. High flavonoid containing 'Amrapali' could be of great use in processing industry, as many products could be prepared from mango peel [1].

Acidity in terms of per cent citric acid values ranged from 0.64 to 1.39% citric acid (Table 4). The acidity per cent was high in green cultivars followed by red and yellow cultivars. During ripening reduction in acidity by almost 50 percent was observed in all the cultivars (Fig. 1f). Drastic reduction (2% to 0.5%) in acidity was observed which later got decreased from initial 80% maturity to ripen stage. Hence, mango peel were found to be rich in acidity content (Table 4).

Acidity decides the flavor of a product [24] and hence it is an important trait in processing industry. Titratable acidity ranged from 0.64 to 1.39 per cent citric acid among different coloured cultivars of mango (Table 4) and showed reduction during ripening of fruit (Fig.1f). So far, studies were focused on acidity contents in mango pulp. The acidity of ripe mango pulp varied from 0.25 to 1.81% [36]. Considering acidity

content in the peel, it could be utilized as an ingredient in processing industries. In the present study, mango peel harvested at 80% and 100% maturity was observed with high acidity, later it decreased drastically during ripening.

Conclusions

In this study, mango peel was examined for morphological, colour and biochemical studies in different coloured mango cultivars during ripening. A wide diversity/ variation was observed amongst the different coloured cultivars for various morphological descriptors, colour and biochemical parameters. The colour evaluation revealed the peel colours and its intensity amongst fourteen evaluated cultivars. The differences in green, yellow and red nature of peel colours was demonstrated among mango cultivars through parameters ('L', 'a', 'b', 'c' and 'h'). Also their changing patterns during ripening process are reported here. The higher content of total chlorophyll, carotenoids and anthocyanins were noticed in peel of green, yellow and red coloured cultivars respectively. Mango peel were found to be associated with a decrease of chlorophyll content and increase in the total carotenoid, and total anthocyanin contents during ripening. Total flavonoids in peel of coloured cultivars increased and titratable acidity decreased during ripening of fruit. Hence, this study reports some morphological and biochemical parameters showing wide diversity for mango peel characters amongst coloured cultivars helpful in breeding (selection of parents) and processing (peel utilization) of fruits.

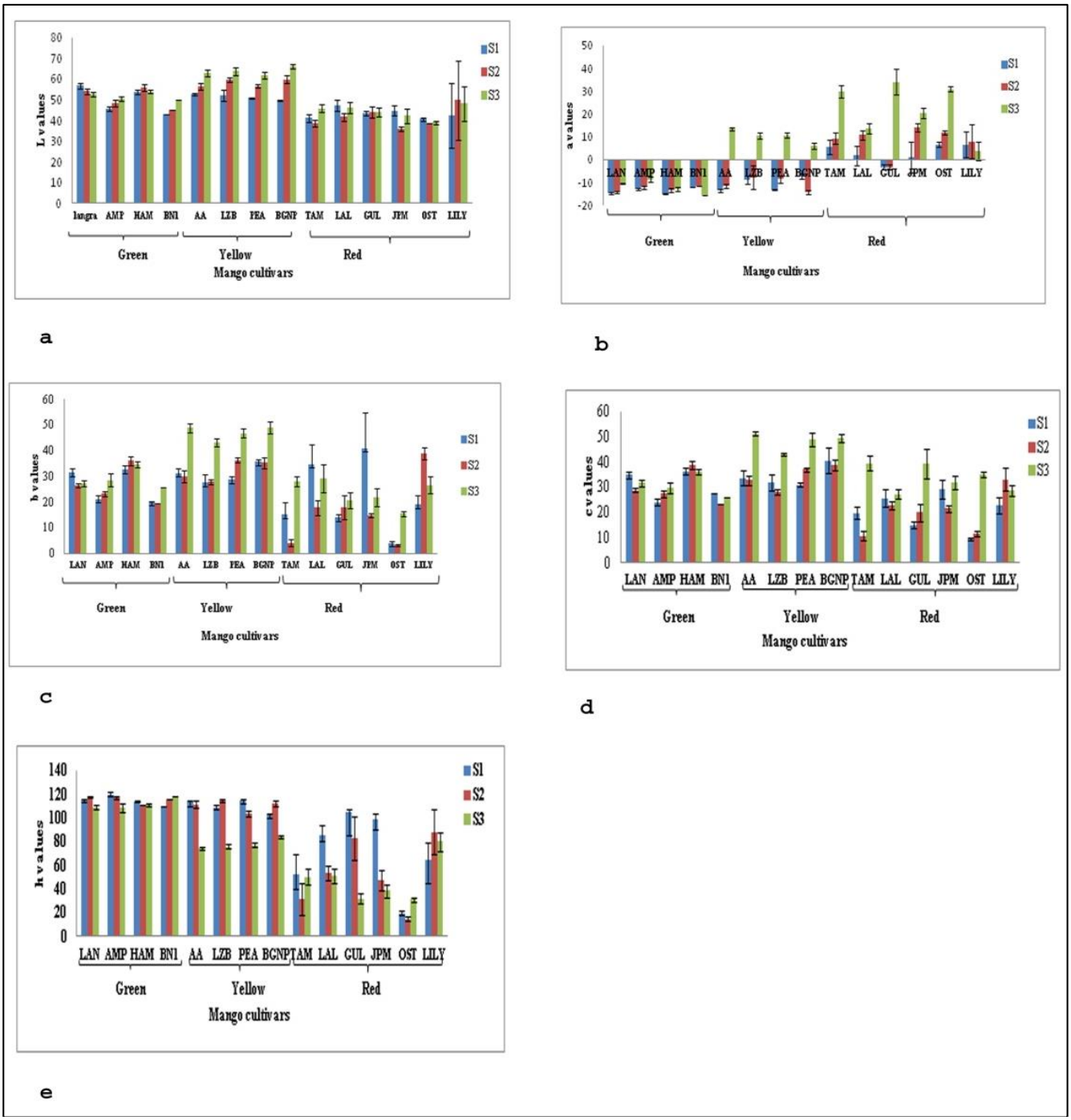

Fig 1: Pattern of color changes during ripening. a. L value b. a value c. b value c. C value and d. h (hue angle). S1 (80% maturity), S2 (100% maturity) and S3 (fully ripened stage); Codes of different cultivars are: LAN ('Langra'), AMP ('Amrapali'), HAM ('Hamlet'), BN1 ('Bombay No. 1'), AA ('Arka Anmol'), LZB ('Lazzat Baksh'), PEA ('Peach'), BGNP ('Banganapalli'), TAM ('Tommy Atkins'), LAL ('Lalmuni'), GUL ('Gulabi'), JPM ('Janardhan Pasand'), OST ('Ostin') and LILY ('Lily'). Data of three varieties Amrapali, Arka Anmola and Janardhan Pasand have been published by Karanjalker *et al*., (2017) [15] with different objectives. Bar represents the standard error mean

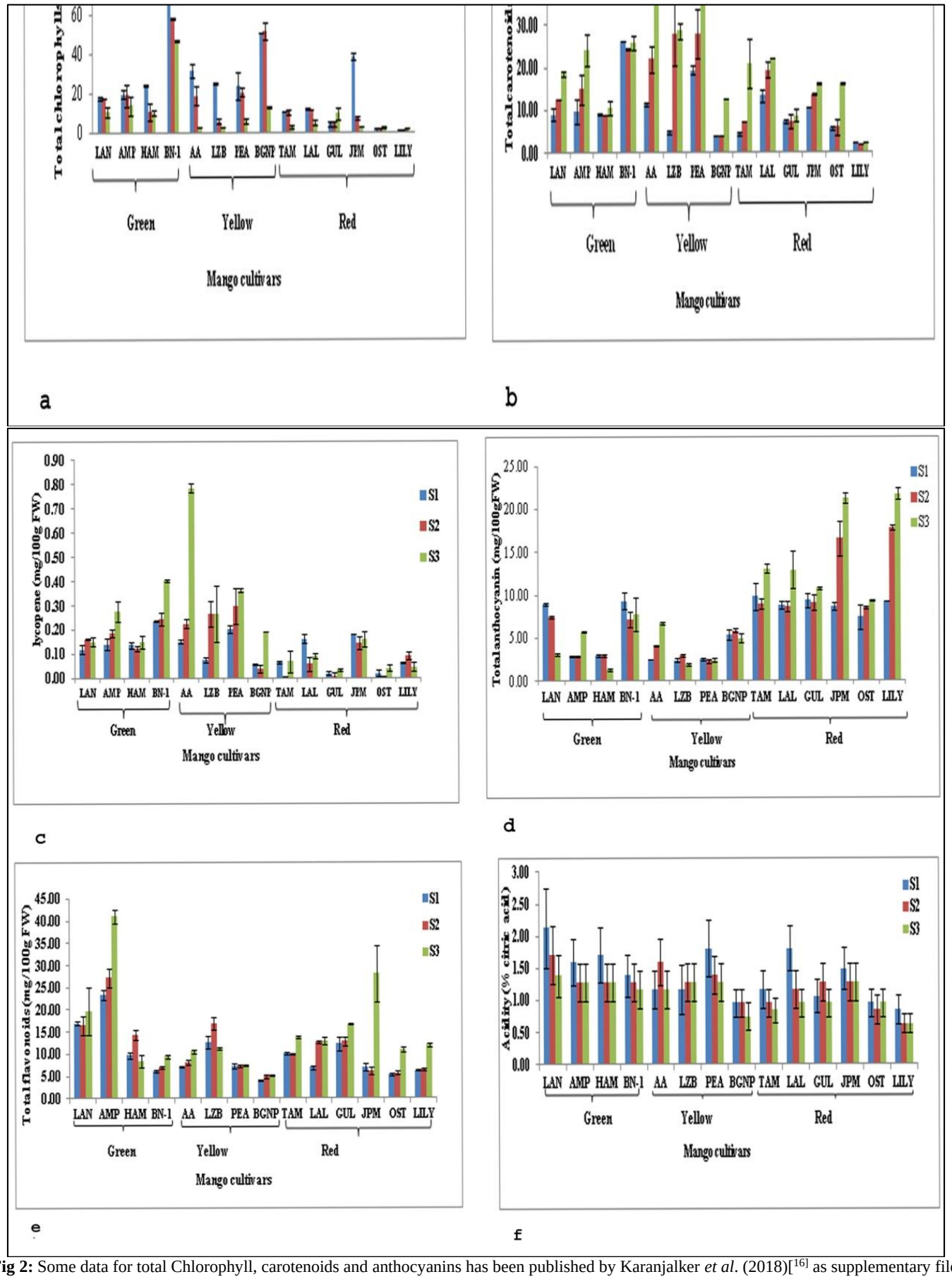

Fig 2: Some data for total Chlorophyll, carotenoids and anthocyanins has been published by Karanjalker *et al*. (2018)[16] as supplementary file with different objective. Pattern of biochemical content changes during ripening. a. Chlorophyll b. Carotenoids c. Lycopene d. Anthocyanin e. Flavonoids, f. Acidity. S1 (80% maturity), S2 (100% maturity) and S3 (fully ripened stage); Codes of different cultivars are: LAN ('Langra'), AMP ('Amrapali'), HAM ('Hamlet'), BN1 ('Bombay No. 1'), AA ('Arka Anmol'), LZB ('Lazzat Baksh'), PEA ('Peach'), BGNP ('Banganapalli'), TAM ('Tommy Atkins'), LAL ('Lalmuni'), GUL ('Gulabi'), JPM ('Janardhan Pasand'), OST ('Ostin') and LILY ('Lily'). Bar represents the standard error mean of three replications.

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