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PHYSICO-CHEMICAL CHANGE OF INDIAN OLIVE (*ELAEOCARPUS FLORIBUNDUS* BL.) FRUIT OCCURRING AT DIFFERENT FRUIT AGES

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ABSTRACT
Stage of fruit maturity at harvest is the most important factor determining storage life and final fruit quality. Fruit ripening involves several different processes, both metabolic changes and physical softening. Ripening of the fruit involves a series of complex biochemical reactions such as hydrolysis of starch, production of carotenoids, anthocyanins and phenolics and the formation of volatile compounds. There is less information regarding physico-chemical changes that may occur during different stages of maturity of Indian olive. Keeping these in view, the present study was carried out during 2015-17 to study the physico-chemical changes during the growth and developmental stages. In this experiment, different physical (Fruit weight, specific gravity, length & breadth) and chemical (TSS, titratable acidity, total sugar, ascorbic acid & total phenol) observations were taken at 5 days interval. Fruit weight was increased from 8.94g (5 days after fruit set) to 22.49g (40 days after fruit set). Highest TSS (9.96obrix) and highest ascorbic acid (48.86mg/100g) was recorded at 40 days after fruit set and it was declined at senescence stage. The growth and developmental stages followed single sigmoid growth curve following cubic trend model & optimum maturity was reached at 40 days after fruit set.

KEYWORDS: Indian olive; ripening; fruit weight; TSS; developmental stages

INTRODUCTION
Importance of minor fruits is increasing day by day with that of major fruits due to increase population pressure. Indian Olive (*Elaeocarpus floribundus* Bl.), also known belongs to the family of Elaeocarpaceae, is a medium to tall evergreen tree. Flowers bloom during April-May and fruits mature for harvest in October-November. Fruits are greenish in colour, single seeded, the shape resembles to that of the olive fruit. Fruits are single seeded, drupe and the edible portion of the fruit is the mesocarp (Mani and Bhowmick 2017). Optimum fruit quality depends upon a number of factors, including the fruit developmental stage at the point of harvest and the subsequent changes during the period of post-harvest maturation. Stage of fruit maturity at harvest is the most important factor determining storage life and final fruit quality. Ripening of the fruit involves a series of complex biochemical reactions such as hydrolysis of starch, production of carotenoids, anthocyanins and phenolics and the formation of volatile compounds. The nutrient content of freshly harvested edible plants varies, and these variations result from interplay of a number of factors, chiefly genetics, sunlight, reliable rainfall, topography, soils, location, season, fertilization of soils and maturity (Lima et al. 2005). Dey et al (2017) found that the matured Jalpai fruit contained 9.98°Brix total soluble solids, 0.63% titrable acidity, 8.29% total sugar and 49 mg/100g of pulp ascorbic acid. It recorded high moisture content (77.63%) with pH of 5.52, 2.75% of ash and 1.5% of crude fibre. The data also revealed that the fruit become a potential source of food energy value (94.44 kcal/g), fat content (2.54%), protein content (0.72%) and total carbohydrate content (19.65%). The physico-chemical changes associated with maturity and ripening of many major fruits have been studied extensively but literature in respect of physico-chemical changes associated with maturity and ripening of minor fruits are scanty. Keeping these in view, the present experiment was done with the following objective to study the physico-chemical changes during the growth and developmental stages.

MATERIALS AND METHODS
In this experiment, firstly several flowering shoots were tagged throughout the canopy and just after fruit set all the observations were recorded until senescence stage. The observations were recorded at 5 (five) days interval starting from

fruit set (Plate 1). The fruits were collected at different developmental stages from the Fruits Research station of Mondouri, Bidhan Chandra Krishi Viswavidyalaya in the field of RKVY Ad-hoc Project on ‘Survey, collection, conservation and maintenance of under-utilized fruits’ in the plains of New Alluvial zone of West Bengal.

A **B** **C**

D **E**

Plate I. Indian olive fruits at different developmental stages: (A): 15days after fruit set; (B): 25 days after fruit set; (C): 35 days after fruit set; (D): 40 days after fruit set; (E): 45 days after fruit set

After harvesting the fruits were properly washed in running water and surface dried and subjected for different physico-chemical testing at laboratory of Department of Fruits & Orchard Management and Quality Control Laboratory, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal during the year 2015 to 2017. Observation on physical characters like fruit weight, fruit length and breadth, specific gravity and fruit colour were recorded as well as the biochemical constituents like total soluble solids, total sugar, reducing sugar, non reducing sugar, titratable acidity, ascorbic acid, total phenol, moisture, TSS/acid ratio, sugar/acid ratio were estimated at each sampling date following the standard procedures. The fresh weight of whole fruits were determined by electronic (digital) balance after removal of pedicels and recorded in grams. Specific gravity was calculated following water displacement method. The amount of displaced water was collected in a tray and measuring cylinder was used for obtaining the volume of fruits. It was calculated by the formula of water volume divided by the weight of the fruit. Length and breadth of each fruit was measured with the help of digital Vernier Calipers in Centimeter scale. Fruit colour was recorded by visual observations. TSS content of the fruit was recorded with the help of hand refractometer by the principle of total refraction which was calibrated at 0^0 Brix at 20°C with the help of a temperature correction correlation chart. A few drops of fruit juice from each sample were installed on the plate to record the refractometer reading, in ^{0}Brix (Mazumdar and Majumder 2003). The titratable acidity was measured by titrate the extracted juice against standard alkali (N/10 NaOH) solution using phenolphthalein as an indicator and expressed as percentage of acidity in terms of citric acid (Rangana 1977). The total sugar and reducing sugar content were estimated with the help of freshly made mixture containing equal volumes of Fehling‘s solution A & B by copper reducing method (AOAC 1984) using methylene blue as an indicator and was expressed in percentage (Mazumdar and Majumder 2003). For determining the non reducing sugar content in percentage the value of reducing sugar content of the fruit pulps was substracted from the value of total sugar content and the results was multiplied by 0.95 (AOAC 1984). Ascorbic acid contents of fruits were estimated by following the procedure as described by Ranganna (1977) using 2,6-dichiorophenol indophenol dye expressed as mg per 100 g of fruit pulp. Total phenolics of fruits was estimated based on the principle that phenols react with an oxidizing agent phosphomolybdate in Folin-Ciocalteu reagent under alkaline conditions and result is the formation of a blue coloured complex, the molybdenum blue which is measured at 650nm colorimetrically by UV/Vis spectrometer (Perkin Elmer, Lambda 25) and expressed as mg per 100g fruit pulp (Bray and Thorpe 1954). First of all, weight of empty petridish with cover was taken and 5 gm of sample was placed on it. Then the crucible was placed in an air oven (thermostatically controlled) and dried at a temperature of 80ºC for 24 hours, till constant weight was obtained. After drying, the petridish was removed from the oven and cooled in desiccators. It was then weighed with cover glass. From these weights the percentage of moisture in food samples was calculated as follows: % Moisture = (Loss in weight/Weight of sample) X 100. TSS acid ratio was calculated by dividing the value of TSS by the value of titratable acidity of the fruits. Sugar acid ratio was calculated by dividing the value of total sugar by the value of titratable acidity of the fruits. Analysis of variance (one way classified data) for each parameter was performed using op stat software (online version). The statistical analysis was done by following completely randomized design (CRD) as per Gomez and Gomez (1984). The significance of different sources of variation was tested by error mean square by Fischer-Snedecor's 'F' test at probability level of 0.05 percent.

RESULTS

Fruit weight

The data pertaining to fruit weight (g) was represented in Table 1. From the data, it has been found that fruit weight was increased throughout the growth period except in senescence stage (at 45 DAFS). The initial fruit weight taken 5 DAFS was 8.94g, 8.95g while maximum fruit weight (22.49g, 22.50g) was found at fully mature stage (40 DAFS) in two years respectively. The increasement of fruit weight was less upto 10 DAFS and rapid increase was noted thereafter. Statistical analysis showed that fruit weight at all days after fruit set were significant.

Table 1. Effect of developmental stages on fruit weight (g), specific gravity and fruit colour

DAFS	Fruit weight (g)		Specific gravity		Fruit colour	
	2016	2017	2016	2017	2016	2017
5	8.94	8.95	0.65	0.67	Green	Green
10	10.72	10.74	0.67	0.69	Green	Green
15	12.55	12.56	0.75	0.78	Green	Green
20	14.97	14.99	0.77	0.79	Light green	Light green
25	17.25	17.26	0.84	0.87	Light green	Light green
30	19.07	19.11	0.94	0.96	Light green	Light green
35	21.68	21.71	0.98	0.99	Light green	Light green
40	22.49	22.50	1.03	1.04	Fade green	Fade green
45	22.08	22.07	1.00	1.01	Fade green	Fade green
C.D. ($p \leq 0.05$)	0.124	0.139	0.043	0.040	-	-
SE(m) (±)	0.042	0.048	0.015	0.014	-	-

Specific gravity

Specific gravity showed an increasing trend with the concomitant increase in growth upto maturity of fruits (Table 1). Maximum specific gravity (1.03, 1.04) was reported in 40 DAFS in two years. Significant difference in specific gravity was recorded in all pairs of treatments.

Fruit colour

Initially (5-15 days after fruit set) the fruit colour was green; light green was found during 20-35 days after fruit set and after that 40-45 days after fruit set the fade green colour was developed. This fade green colour was indicated as colour of the ripe fruits.

Fruit length

The data presented in Table 2 revealed that length of the fruit was 1.48cm and 1.50cm only at 5 DAFS in two years. It increased considerably during the growth period and attained 4.46 cm and 4.48 cm at 40 DAFS i.e. at harvest stage in two years respectively. At 45 DAFS the length was reduced (4.40 cm and 4.41 cm in both the two years). All the data were statistically significant.

Table 2. Effect of developmental stages on fruit length and breadth

DAFS	Fruit length (cm)		Fruit breadth (cm)	
	2016	2017	2016	2017
5	1.48	1.50	0.45	0.48
10	1.85	1.85	0.69	0.71
15	2.11	2.11	0.91	0.94
20	2.43	2.43	1.14	1.17
25	3.54	3.54	1.34	1.37
30	3.83	3.83	1.95	1.97
35	4.13	4.15	2.40	2.41
40	4.46	4.48	2.84	2.83
45	4.40	4.41	2.76	2.76
C.D. ($p \leq 0.05$)	0.055	0.082	0.050	0.060
SE(m) (±)	0.019	0.028	0.017	0.021

Fruit breadth

Changes in fruit breadth followed the same pattern as it was found in fruit length. Initially the fruit breadth was minimum and it was increased with the advancement of age of fruit (Table 2) in both the two years. Minimum (0.45 cm and 0.48

cm) and maximum (2.84 cm and 2.83 cm) breadth of fruit was noted at 5 DAFS and 40 DAFS in both the two years respectively. Significant difference in fruit breadth was recorded in all pairs of treatments.
The fruit growth of Indian Olive in terms of fruit weight, length and breadth took place in three distinct phase exhibiting a simple sigmoid growth curve. During phase I, the growth of fruit was slow upto 20 days after fruit set, phase II was the rapid growth phase upto 35 days after fruit set and phase III was the final phase which commenced from 40 days after fruit set to 45 days after fruit set.

Total Soluble Solids (TSS)
The data related to TSS was presented in Table 3. From the table it has been found that initially TSS was very low (8.10ºBrix and 8.12ºBrix) but it was increased throughout the growth period. At the mature stage TSS become 9.96ºBrix and 9.98ºBrix in successive two years. Afterwards, the value was reduced (9.83ºBrix) in both the two years at 45 DAFS onwards. All the data were statistically significant.

Table 3. Effect of developmental stages on TSS (ºBrix) and titratable acidity (%)

DAFS	TSS (ºBrix)		Titratable acidity (%)	
	2016	2017	2016	2017
5	8.10	8.12	0.49	0.51
10	8.34	8.36	0.51	0.52
15	8.72	8.74	0.53	0.54
20	9.09	9.11	0.56	0.57
25	9.27	9.30	0.58	0.60
30	9.48	9.51	0.63	0.65
35	9.75	9.78	0.67	0.68
40	9.96	9.98	0.64	0.65
45	9.83	9.84	0.61	0.62
C.D. ($p \leq 0.05$)	0.034	0.034	0.026	0.027
SE(m) (±)	0.012	0.012	0.009	0.009

Titratable acidity
From Table 3, it was found that like previous observations it followed same increasing trend from fruit set to fruit maturity period. Maximum (0.67% and 0.68%) and minimum (0.49% and 0.51%) value was obtained in 5 DAFS and 35 DAFS in both the two years. All the treatments were statistically significant at 5% level of significance.

Total sugar
The data pertaining to total sugar represented in Table 4 revealed that like previous observations similar trend was observed throughout the developmental phase. There was steep increasement in total sugar content the end of the maturity at 40 DAFS, but slowed down senescence onwards. Maximum content (6.43% and 6.45%) was recorded in 40 DAFS in both the two years. All the data were statistically significant.

Reducing sugar
The data of reducing sugar was presented in Table 4. From the data presented in table, it was found that like total sugar content, it followed the similar pattern throughout the growth period. The reducing sugar content was increased from fruit set to 40 DAFS. All the data were statistically significant.

Table 4. Effect of developmental stages on total sugar (%) and reducing sugar (%)

DAFS	Total sugar (%)		Reducing sugar (%)	
	2016	2017	2016	2017
5	5.30	5.32	0.96	0.98
10	5.37	5.39	1.01	1.03
15	5.48	5.51	1.12	1.15
20	5.63	5.66	1.25	1.26
25	5.70	5.73	1.46	1.48
30	5.91	5.94	1.61	1.63
35	6.09	6.19	1.84	1.84
40	6.43	6.45	1.97	1.98
45	6.38	6.40	1.94	1.94
C.D. ($p \leq 0.05$)	0.033	0.083	0.021	0.024
SE(m) (±)	0.011	0.029	0.007	0.008

Non-reducing sugar
From Table 5 it has been found that non-reducing sugar content did not follow any systematic pattern. Initially the amount was increased from 5 DAFS (4.12%, 4.12%) to 20 DAFS (4.16%, 4.18%), decrease at 25 DAFS (4.03%, 4.04%), again

increase at 30 DAFS (4.09%, 4.10%), and decrease at 35 DAFS (4.04%, 4.13%) having highest value at 40 DAFS (4.24%, 4.25%) in both the two years respectively. All data were statistically significant.

Table V. Effect of developmental stages on non- reducing sugar and ascorbic acid

DAFS	Non-reducing sugar (%)		Ascorbic acid (mg/100g)	
	2016	2017	2016	2017
5	4.12	4.12	36.23	36.26
10	4.14	4.14	37.16	37.18
15	4.14	4.14	38.44	38.46
20	4.16	4.18	39.75	39.77
25	4.03	4.04	41.70	41.72
30	4.09	4.10	43.95	43.98
35	4.04	4.13	46.57	46.59
40	4.24	4.25	48.86	48.88
45	4.22	4.23	48.75	48.77
C.D. ($p \leq 0.05$)	0.035	0.080	0.056	0.057
SE(m) (±)	0.012	0.027	0.019	0.020

Ascorbic acid

Ascorbic acid content is one of the indexes for the optimum stage of harvest of the fruit. The ascorbic acid content (Table 5) in fruit exhibited an increasing trend from 5 DAFS (36.25 mg/100g) to 40 DAFS (48.87 mg/100g). Maximum ascorbic acid content of 48.87 mg/100 g was accumulated till the fruit reaches to the full maturation phase and then it started declining as the maturation advanced. Statistical analysis indicated that all the treatments were significantly different.

Total phenol

Total phenol content (Table 6) was observed to be an index of fruit development and maturation. The rate of phenols accumulation was slow at the beginning of fruit growth but during the exponential growth phase of the fruit, total phenolic content was increased significantly (23.96 mg/100g, 23.99 mg/100g) till 40 DAFS in both the two years. It was declined at 45 DAFS (23.84 mg/100g, 23.86 mg/100g). Statistical analysis indicated that all the treatments were significantly different.

Table VI. Effect of developmental stages on total phenol and moisture

DAFS	Total phenol (mg/100g)		Moisture (%)	
	2016	2017	2016	2017
5	15.98	16.01	61.48	61.51
10	16.46	16.49	64.25	64.27
15	17.37	17.40	65.63	65.65
20	19.27	19.29	69.86	69.88
25	20.55	20.58	70.03	70.04
30	20.75	20.77	72.37	72.38
35	23.17	23.20	74.10	74.11
40	23.96	23.99	75.53	75.54
45	23.84	23.86	75.47	75.46
C.D. ($p \leq 0.05$)	0.068	0.066	0.065	0.074
SE(m) (±)	0.023	0.023	0.022	0.025

Moisture

The data related to moisture was presented in Table 6. Initially the moisture content was increased upto 40 DAFS (75.53%, 75.54%) and afterwards it was declined in both the two years. The data were statistically significant.

TSS Acid ratio

From the Table 7 it has been found that TSS Acid ratio was decreased progressively till 35 DAFS (9.12, 9.14). After that the ratio was increased. It attained the maximum value (16.72, 15.95) at 5 DAFS in both the two years. All the treatments were statistically significant at 5% level of significance.

Table VII. Effect of developmental stages on TSS acid ratio and sugar acid ratio

DAFS	TSS acid Ratio		Sugar acid Ratio	
	2016	2017	2016	2017
5	16.72	15.95	10.94	10.44
10	16.54	16.10	10.65	10.38
15	16.63	16.31	10.45	10.27
20	16.40	15.94	10.15	9.89

25	16.00	15.44	9.84	9.52
30	15.16	14.75	9.46	9.21
35	14.61	14.43	9.12	9.14
40	15.50	15.30	10.01	9.89
45	16.05	15.93	10.42	10.36
C.D. ($p \leq 0.05$)	0.761	0.775	0.472	0.499
SE(m) (±)	0.261	0.266	0.162	0.171

*DAFS – Days after fruit set

Sugar Acid ratio

From the Table 7 it has been found that TSS Acid ratio was decreased progressively from 20 DAFS (16.40, 15.94) till 35 DAFS (14.61, 14.43). After that the ratio was increased. It attained the maximum value (10.94, 10.44) at 5 DAFS in both the two years. All the treatments were statistically significant at 5% level of significance.

Trend analysis

Fruit weight

The trends in fruit weight of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 1).

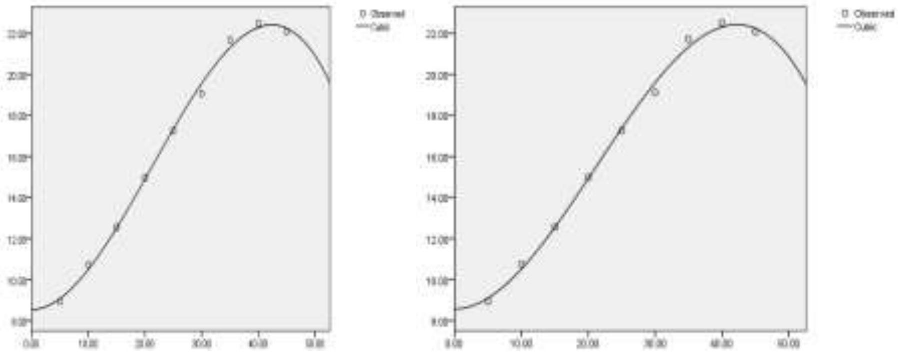

Figure 1. Cubic model showing fruit weight in Indian olive during 2015-17

Fruit length

The trends in fruit length of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 2).

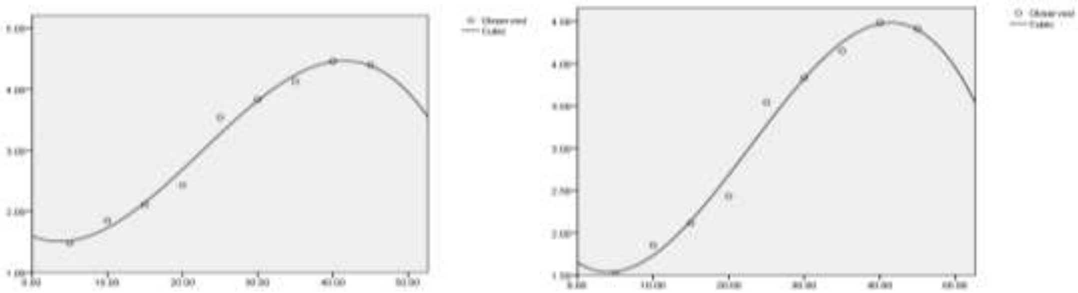

Figure 2. Cubic model showing fruit length in Indian olive during 2015-17

Fruit breadth

The trends in fruit breadth of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 3).'

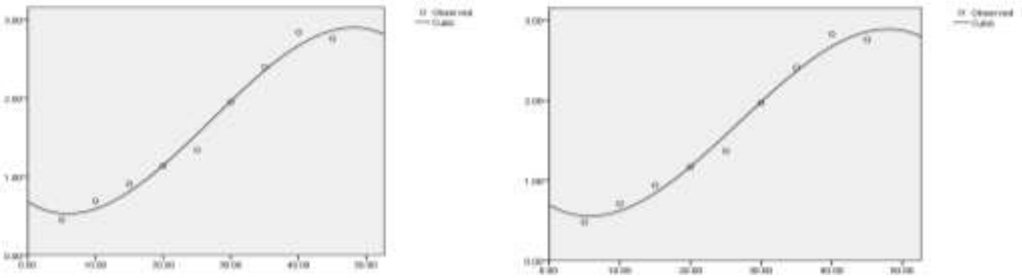

Figure 3. Cubic model showing fruit breadth in Indian olive during 2015-17

Specific gravity

The trends in specific gravity of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 4).

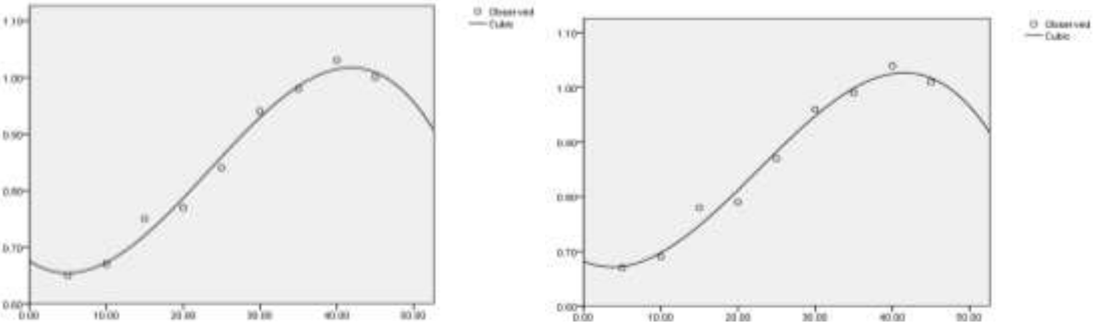

Figure 4. Cubic model showing specific gravity in Indian olive during 2015-17

TSS

The trends in TSS of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 5).

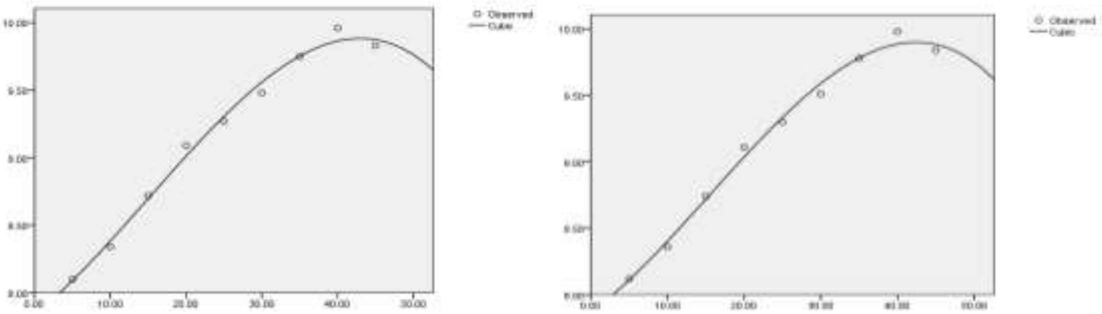

Figure 5. Cubic model showing TSS in Indian olive during 2015-17

Titratable acidity

The trends in titratable acidity of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 6).

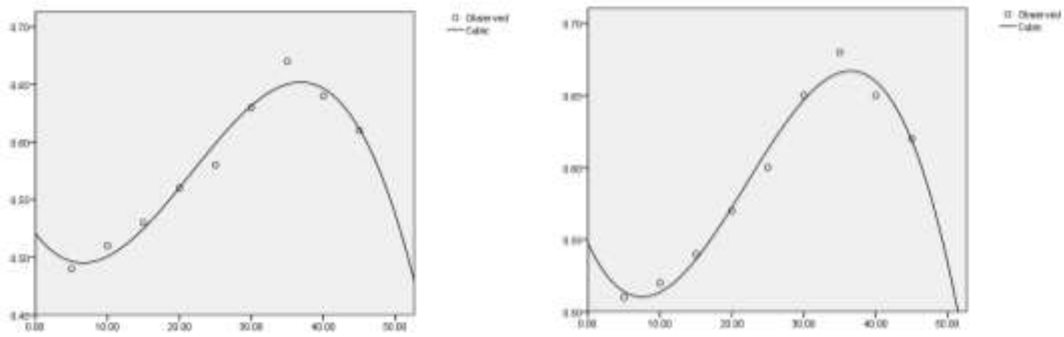

Figure 6. Cubic model showing titratable acidity in Indian olive during 2015-17

Total sugar

The trends in total sugar of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 7).

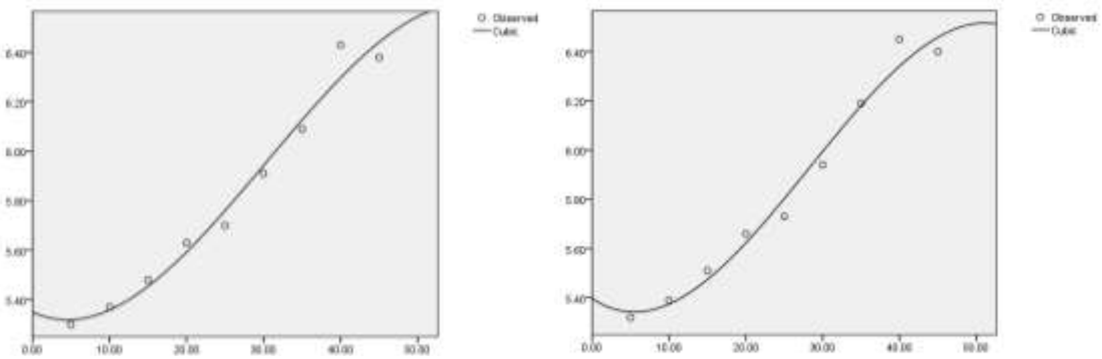

Figure 7. Cubic model showing total sugar in Indian olive during 2015-17

Reducing sugar

The trends in reducing sugar of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 8).

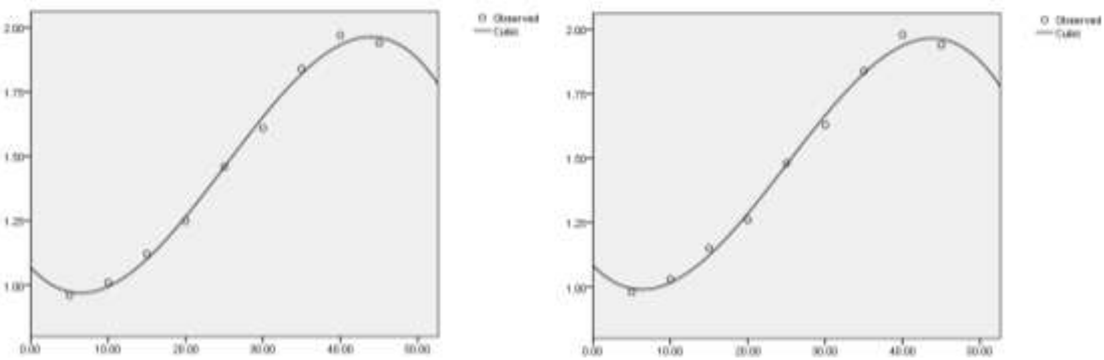

Figure 8. Cubic model showing reducing sugar in Indian olive during 2015-17

Non-reducing sugar

The trends in non-reducing sugar of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 9).

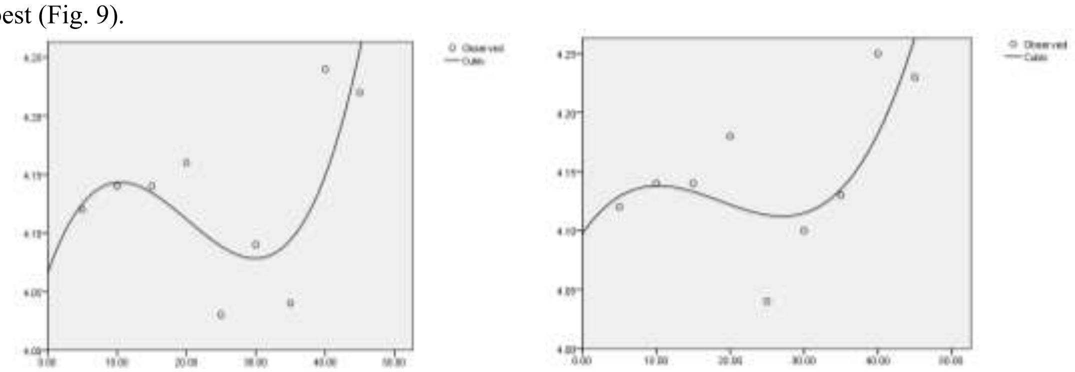

Figure 9. Cubic model showing non-reducing sugar in Indian olive during 2015-17

Ascorbic acid

The trends in ascorbic acid of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 10).

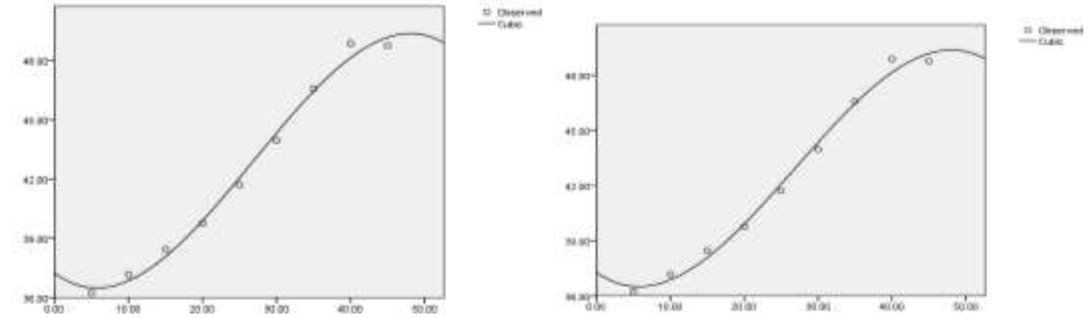

Figure 10. Cubic model showing ascorbic acid in Indian olive during 2015-17

Total phenol

The trends in total phenol of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 11).

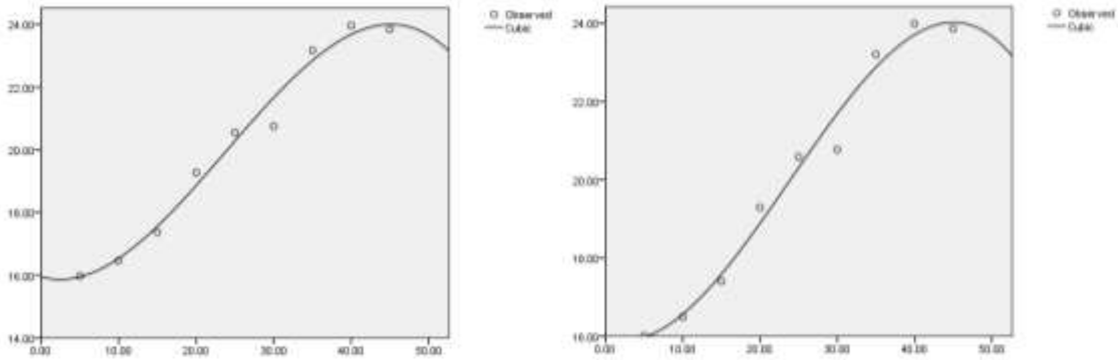

Figure 11. Cubic model showing total phenol in Indian olive during 2015-17

Moisture

The trends in moisture of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 12).

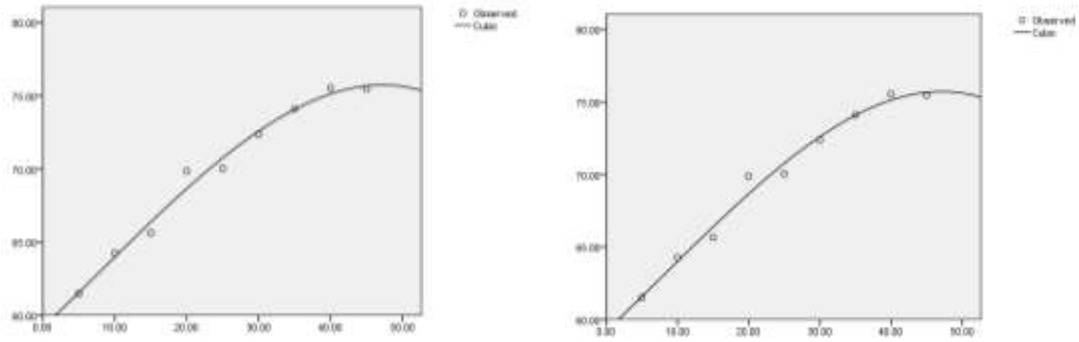

Figure 12. Cubic model showing moisture in Indian olive during 2015-17

TSS acid ratio

The trends in TSS acid ratio of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 13).

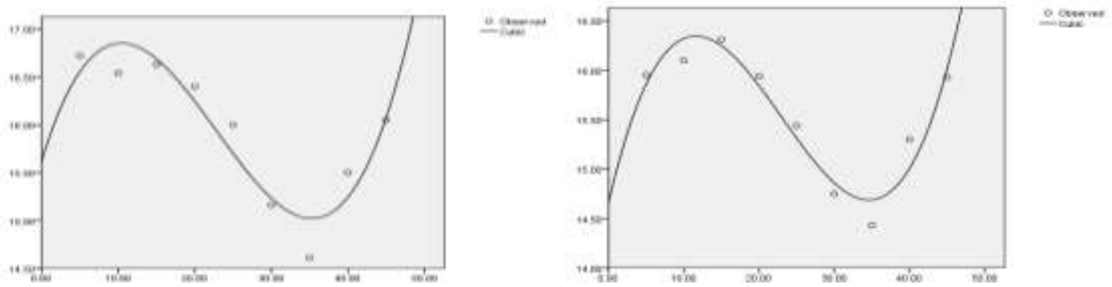

Figure 13. Cubic model showing TSS acid ratio in Indian olive during 2015-17

Sugar acid ratio

The trends in sugar acid ratio of Indian olive during developmental stages of 2015-16 showed a 2nd degree equation. The cubic model (curve) fits the best. For 2016-17 the trend also showed a 2nd degree equation where cubic model (curve) fit the best (Fig. 14).

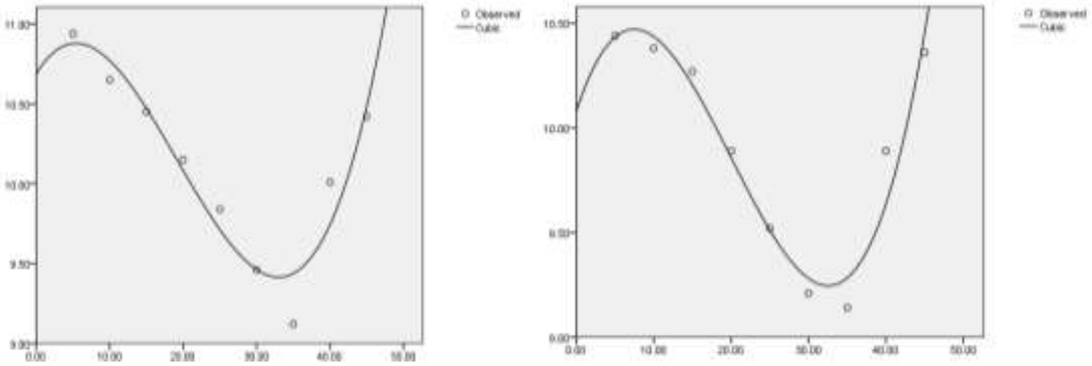

Figure 14. Cubic model showing sugar acid ratio in Indian olive during 2015-17

DISCUSSION

Bhowmick (2017) reported the fruit weight of ripe Indian olive was varied from 15.78g to 22.46 g. The slow growth in the early stages followed by a rapid increase might be attributed to cell division in the early stages and cell enlargement in the later stage (Singha 2004). Dey et al. (2017) found similar green colour in ripe fruit of Indian olive. Similar fruit length in mature stage was reported earlier by Bhowmick (2017), Mani and Bhowmick (2017). Similar result of fruit breadth in ripe stage was reported earlier by Bhowmick (2017), Mani and Bhowmick (2017). Bhowmick (2017) reported TSS content of different accessions was varied from 8.20 to 11.33^{0}Brix. The low level of TSS at early stage might be due to less accumulation of metabolites in the substrates. The increase in TSS content at the later stage might be due to result of degradation of starch with the advance of harvesting time (Singha 2004). Titratable acidity content in mature stage was reported to be 0.65-0.72% by Ghosh et al (2017) and 0.63% by Dey et al (2017). Ghosh et al (2017) and Dey et al (2017) observed that the TSS content of fruits reached 9.96-9.99ºBrix in matured stage. Bhowmick (2017) found that total sugar content was ranged from 5.73-7.34% in mature stage. Dey et al (2017) and Ghosh et al (2017) recorded total sugar content of 8.29% in mature fruit. The increase of total sugar content till ripening was mainly due to conversion of carbohydrates particularly starch into sugars with subsequent increase of TSS content (Singha 2004). Reducing sugar content was found to be varied from 1.90-2.40% in different accessions grown in Northern parts of West Bengal (Bhowmick 2017; Mani and Bhowmick 2017). The increase of reducing sugar content till ripening was mainly due to conversion of carbohydrates particularly starch into sugars with subsequent increase of TSS content (Singha 2004). Ghosh et al (2017) and Dey et al (2017) recorded ascorbic acid content of 48.97-48.98mg/100g and 49mg/100g in ripe fruits of Indian Olive respectively. The increase in ascorbic acid content upto maturity might be attributed due to the adequate supply of hexose sugars via photosynthetic activity. The reduction in later stages might be due to enzymatic loss of ascorbic acid through oxidation (Singha 2004). Hardainiyan et al (2015) reported phytochemical investigation of fruit extract of *Elaeocarpus ganitrus* and found total phenolic content of 232.24±0.31mg/g in mature fruits.

CONCLUSION

In case of growth and developmental stages for fruit ripening and maturity, all the fruit growth resembled simple sigmoid growth curve following cubic trend model. The physical and biochemical changes were found very prominent from fruit set to fruit ripening. In different developmental stages, all the physic-chemical characters was significantly increased upto the maturity stage and thereafter it was decreased due to senescence stage. In Indian olive, changes in colour were not so prominent in the mature stage but the increasement of weight and size was found to be the important visual observation for maturity judgment.

Author contributions

KD, AG: investigation, visualisation, writing original draft; AG, SD, MM: formal analysis; KD, SM, RM: writing – reviewing and editing, KD, PD, AG: Conceptualisation, formatting and resources.

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Data availability statement

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

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