American Journal of Plant Sciences, 2016, 7, 958-966
Published Online April 2016 in SciRes. http://www.scirp.org/journal/ajps
http://dx.doi.org/10.4236/ajps.2016.76091

Effect of Altitude and Maturity Stages on Quality Attributes of Mandarin (*Citrus reticulata* Blanco)

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Received 23 February 2016; accepted 26 April 2016; published 29 April 2016

Abstract

Mandarin (*Citrus reticulata* Blanco) is a premier fruit crop which ranks in first position of the total fruit industry in Nepal. Studies were conducted to assess the maturity indices and quality parameters of mandarin at three altitudes *i.e.* 1300 m·asl, 1000 m·asl, and 700 m·asl with six maturity stages *i.e.* 11 Oct, 21 Oct, 31 Oct, 10 Nov, 20 Nov, and 30 Nov. The most important and reliable judging criteria of fruit maturity in mandarin *i.e.* fruit weight, external fruit colour, firmness, TSS, acidity, and TSS/Acid ratio, and vitamin C were experimented. The experiment results revealed that 1000 m·asl location was showed the highest fruit weight (104.9 g) and juice percentage (55.23) followed by 1300 m·asl altitude (99.5 g and 53.75% respectively) at 20th of November. The maturity advanced at lower altitude with 50 percent yellow orange rind colour, 10.98 TSS/acid ratio and 4 kg/cm^2 firmness from 10th November at lower altitudes whereas it was appeared in 20th November at higher altitudes. The TSS/acid ratio was significantly higher (10.98) in the fruits of 700 m·asl as compared to 1300 m·asl (9.76) on 10th November, however, on 20th November 1300 m·asl showed the highest ratio (17.76). The fruit weight, juice content, TSS was found in increasing trends up to 20 November and then showed constant and decreasing trend. However, TA, firmness and vitamin C were showed in decreasing trends with time. The 1000 - 1300 m·asl was the best location for the mandarin production and 10-20 November was the best period for the mandarin harvesting for optimum maturity.

Keywords

Maturity, Physico-Chemical, Quality Parameters, Firmness, Total Soluble Solid

How to cite this paper: Rokaya, P.R., Baral, D.R., Gautam, D.M., Shrestha, A.K. and Paudyal, K.P. (2016) Effect of Altitude and Maturity Stages on Quality Attributes of Mandarin (*Citrus reticulata* Blanco). *American Journal of Plant Sciences*, **7**, 958-966. http://dx.doi.org/10.4236/ajps.2016.76091

1. Introduction

Mandarin (*Citrus reticulata* Blanco) is a premier fruit crop which ranks in first position of the total fruit industry in Nepal. It is commercially viable and cash generating high value fruit crop grown largely across the mid-hills of the country. Commercially, it is grown in 42 districts and is bumping up for its coverage in production and productivity annually. Mid-hills of Nepal with sub-tropical climate and distinct winter offer congenial environment for commercialization of citriculture (FDD, [1]). Nepal is endowed with varying agro-ecological diversity and has suitable climate for growing fruits, particularly mandarin. Citrus is also obvious choice because it is by far the most important fruit in Nepal and is grown throughout the hills (APP, [2]). The agro-climatic conditions of mid-hill regions of Nepal account about 1.5 million hectares is stretching from east to west ranging from 750 to 1350 m·msl (Baral, [3]). It is mentioned that minimum suitable altitude for mandarin cultivation is above 750 m·asl (ACD, [4]). Local mandarins grow well from 750 to 1400 m·asl (NCDP, [5]).

Mandarin adversely affect by the altitudes and microclimate. The size, weight, and juice content vary greatly with altitudes; fruits at higher elevation are usually smaller in size and more acidic in taste (Ghosh, [6]). Different altitudes influenced fruit growth periods and the intensity of peel colour in mandarin (Susanto *et al*., [7]). (Barua *et al*., [8]) concluded that physiological loss in weight and juice contents were significantly affected by the stage of maturity. At the minimum maturity standard (SSC/TA) of 8:1 was found dislike range in Navel orange as set by California Department of Food and Agriculture (Obenland *et al.*, [9]). The maturity standards vary from region to region (Devkota *et al.*, [10]). Fruits are harvested when their internal quality is at the best (Ladaniya, [11]). Appropriate maturity stage for harvesting, harvesting methods, storage condition and their treatments should be developed to prolong their shelf life (Ladaniya, [12]).

Mandarin oranges do not keep long and hence it is desirable to harvest them as early as possible, otherwise they shrink, lose weight and may eventually drop off (Rajput, [13]). Late picked fruits have a good internal quality but have shorter shelf life and on the other hand early picked fruits have better shelf life but poor eating quality (Streif, [14]). The fruit increase in length, breadth, and volume unless it matures (Rana, [15]). No and/or scanty work has been done on the maturity indices of mandarin in Nepal. Global booming market emphasizes on external as well as internal quality standards for mandarin fruits. The present studies were, therefore, conducted to find out the optimum time of maturity of mandarin. Thus, such standards may prove an efficient tool in the hands of growers and to regulate the produce in the market at appropriate time.

2. Materials and Methods

The study on effect of altitudes and maturity stages on fruit quality was conducted at Lamjung district during 2012 and 2013. Three locations based on altitudes (around 700 m·asl, around 1000 m·asl, and around 1300 m·asl) with six harvesting date was taken for evaluation. Four trees with uniform size, age and vigour were randomly selected and marked. Five fruits representing the whole mass of different aspects from each tree of each altitude were collected for physicochemical analysis. Fruits were harvested at 10 days interval starting from 230 days after flowering (DAF) *i.e.* 11 October to 280 days after flowering (DAF) *i.e.* 30 November in each year.

Different physicochemical parameters *i.e.* fruit weight, fruit size, rind colour, juice content, volume, TSS, acidity, ascorbic acid were taken. Average fruit weight was recorded with the help of top balance, fruit size was measured with the help of clinometers, rind colour was taken by colour chart, juice content was measured with squeezing and measuring by measuring cylinder, TSS was measured by hand refractometer, acidity, and ascorbic acid were studied as per methods outlined in (AOAC, [16]). The data were tabulated and statistically analysed as mentioned by Gomez and Gomez (Gomez and Gomez, [17]).

3. Results and Discussion

3.1. Fruit Weight

Fruit weight varies with the different maturity stages and altitudes. The fruit weight was increased with the advancement of the maturity in all the altitudes and maturity stages. From the perusal of data dipicted in **Table 1**, the fruit weight was recorded from 230 days after flowering (DAF) *i.e.* 11 October was found 61.80, 73.50 and 54.60 grams respectively in 1300, 1000 and 700 m·asl. The fruit weight was observed in acceleration on 10 November at lower and middle altitude where as its growth was observed rapidly up to 20 November at higher altitude. Increasing trends in fruit weight could be due to accumulation of juice inside the juice sacs. Similar in-

Table 1. Effect on physical characteristics of mandarin fruits at different altitudes and maturity stages.

Altitudes/maturity	Weight (g)	Size (cm)	Diameter (cm)	Specific gravity	Firmness (kg/cm^2)	Rind colour index (1 - 5)
1300 msl						
230 DAF (11 Oct)	61.80	21.09	4.90	0.57	7.38	1
240 DAF (21 Oct)	71.10	25.53	5.16	0.68	7.09	1.13
250 DAF (31 Oct)	79.40	27.15	5.54	0.77	5.55	1.75
260 DAF (10 Nov)	89.30	29.42	5.67	0.96	4.82	2.25
270 DAF (20 Nov)	99.50	30.68	6.14	1.04	4.38	2.72
280 DAF (30 Nov)	94.20	29.31	5.81	1.04	3.71	3.68
1000 msl						
230 DAF (11 Oct)	73.50	24.80	5.20	0.70	6.88	1.00
240 DAF (21 Oct)	86.40	30.17	5.57	0.85	6.28	1.40
250 DAF (31 Oct)	97.30	31.23	5.70	0.96	5.01	2.06
260 DAF (10 Nov)	101.10	32.52	5.72	1.04	4.41	2.88
270 DAF (20 Nov)	104.90	32.82	6.28	1.06	4.01	3.14
280 DAF (30 Nov)	98.10	31.42	5.81	1.05	3.54	4.15
700 msl						
230 DAF (11 Oct)	54.60	21.21	4.74	0.54	5.83	1.00
240 DAF (21 Oct)	66.30	23.57	4.85	0.65	4.85	2.35
250 DAF (31 Oct)	75.00	26.55	5.20	0.76	4.33	2.79
260 DAF (10 Nov)	87.50	28.13	5.50	0.92	3.99	3.38
270 DAF (20 Nov)	85.10	28.12	5.69	0.93	3.39	3.80
280 DAF (30 Nov)	84.20	28.12	5.65	0.92	3.08	4.84
LSD (P = 0.05)	17.08	3.83	0.44	0.18	0.80	0.53

crease in fruit weight was reported by (Deka *et al.*, [18]) in Khasi mandarin, (Bhusal, [19]) in mandarin, (Bal and Chauhan, [20]) in Kinnow mandarin, (Bakhshi *et al.*, [21]) in sweet orange, (Pandey *et al.*, [22]) in kiwifruit, and (Mahajan *et al.*, [23]) in mandarin. Experiments revealed that highest fruit weight was found on 10 November *i.e.* 87.50 gram at lower altitude (700 m·asl), however, the fruit weight was recorded its maximum point *i.e.* 104.92 and 99.49 grams at upper altitudes (1000 and 1300 m·asl respectively) on 20 November, 10 days after lower altitude. The growth of the fruits accelerated rapidly on and around 31 October with the decrease in temperature. Hence, result showed that the efficient growth of the fruits was found in between 10 to 20 November in all altitudes, however, the maximum growth was found on 10 November for lower altitude *i.e.* around 700 m·asl and on and around 20 November for 1000 and 1300 m altitudes. It was interesting to note that at the last picking date (30 November), there was slightly reduction in fruit weight in all altitudes. These findings corroborate with the findings of (Jawanda *et al.*, [24]) and (Bal and Chauhan, [20]) who reported decrease in fruit weight with later stage of ripening of Kinnow mandarin. The decreasing fruit weight might be due to catabolic activities in cell and loss of dry matters in the fruits sac.

3.2. Fruit Size

The fruit size was correlated with the fruit weight. The size of the fruit was observed increased with increase in maturity stage. The studies revealed that the size of the fruit was significantly increased on 21 October to 10

November and then it was noticed gradual and stagnant as shown in **Table 1**. The experiment revealed that fruit size was increased sharply up to 10 November at 700 m·asl altitude and 20 November at 1000 m and 1300 m·asl altitude. In lower altitudes the fruit size reached its maximum point (28.13 cm) on 10 November while in 1300 and 1000 m·asl it reached its maximum point on 20 November (30.68 and 32.82 cm respectively). The minimum fruit size (21.09 cm) was recorded on 11 October at 1300 m·asl followed by 700 m·asl (21.21 cm) and the maximum size of fruit was recorded in 20 November at 1000 m·asl (32.82 cm) followed by 1300 m·asl (30.68 cm) and beyond this point the fruit size seemed declined gradually. (Bhullar, [25]) has reported increase in fruit size in sweet oranges with advancement of maturity level. The increase in fruit size along with increased maturity stage is mainly due to cell division and dry matter accumulation. Hence, by summing up these observations we concluded that the optimum date of harvesting of mandarin is 10 November for lower altitudes and 20 November for higher altitudes.

3.3. Fruit Firmness

The firmness is basic criteria to judge the fruit whether it is ripe or not in the orchards. The firmness is decreases with the increasing level of maturity in all altitude. The fruit firmness was drastic declined during the study period at level of altitude. The perusal from the data shown in **Table 1**, the maximum firmness was observed on 11 October at 1300 m altitudes (7.38 kg/cm^2) and soft rind was recorded in the fruits of lower altitude (6.99 kg/cm^2). At the end of study (30 November) the highest firmness was found in the fruits of 1300 m·asl (3.71 kg/cm^2) and lowest was observed in the fruits of 700 m·asl (3.28 kg/cm^2) because of temperature variability. Fruit softening is attributed to the dissolution of cell wall component and reduction in pectin substances in citrus rind during fruit development and maturation. The fruit firmness was much higher declined in the fruits at lower altitude than the upper altitudes because of high temperature and early ripening physiological activities in the fruits. This finding corroborates with the findings of (Sharma and Singh, [26]) in apple. These findings revealed that lower altitude had early softening of the rind than the higher altitude. The firmness of ripening might be due to largely influenced by cell turgor and composition of cell wall.

3.4. Specific Gravity

The specific gravity was increased with the advancement of the maturity in all the altitudes and maturity stages. The specific gravity was very low on 11 October and then it was seemed drastic increased with the time of maturity and reached the maximum on 10-20 November (**Table 1**). At initial stage the specific gravity was found higher in the fruits of 1000 m·asl (0.70) followed by 1300 m·asl (0.57) and 700 m·asl (0.54) altitudes. The volume of the fruits was found highest in 1000 m·asl on 20 November (1.06) followed by 1300 m·asl (1.04), and lowest specific gravity was observed in 700 m·asl (0.93). These findings are in corroboration with the findings of (Deka *et al*., [18]) in Khasi mandarin (Khokhar and Sharma, [27]) in sweet orange, and (Bhullar, [25]) in sweet orange who reported that increased the specific gravity with advancement of maturity and then decreased with maturity decline. The specific gravity of fruit increases with the progression in maturity index and fruit maturity at harvest determines its quality and storage life (Rana, [15]).

3.5. Rind Colour

Rind colour is a key quality component and plays a vital role in acceptability by consumers. The rind colour at different maturity stage from three altitudes has been given in the **Table 1**. It is quite clear from the data in **Table 1** that the rind colour changed from full green (ranked 1) to full yellow (ranked 5). The rind colour was found significantly ($p > 0.01$) changed over the harvesting dates in all altitudes. At initial stage, the rind colour in all altitudes was found 100 percent green *i.e.* rating 1. These findings are similar with the findings of (Khokhar and Sharma, [27]) in sweet orange. The rind colour was increased with the advancement of maturity. The perusal from the data in **Table 1** shows that the rind colour of all altitudes remained same in initial stage of maturity and then it moved upwards to its maximum points. The index value of rind colour was recorded higher in 1300 m·asl because of lower temperature in higher altitude. Study showed that the fruits of lower altitude (700 m) ripened earlier as compared to 1000 m and 1300 m altitude. Fruit maturation including production of sugars and development of rind colour reached its highest perfection in 14˚C-20˚C and relative humidity also determined the quality. The colour development is associated with loss of texture, increasing sugar content, and decreasing acidity (Rana, [15]).

3.6. Juice Recovery

The juice percentage increased with the increasing level of maturity stages in all altitudes. **Table 2** shows that the initial percentage of juice content was slightly higher in the fruits of medium altitude 1000 m·asl (41.7) with very close to 700 m·asl (41.65), and minimum juice percentage (39.64) was recorded in the fruits of 1300 m·asl . In all the altitudes, the percentage of juice continued to increase up to 20th November and then it showed constant or declined. In 1000 m·asl and 1300 m·asl altitudes the juice content sharply accelerated to the date of 20 November whereas in 700 m·asl altitude the juice content sharply increased to the date of 10 November. The maximum juice percentage (55.23) was found in the fruits of 1000 m·asl altitude on 20th November followed by 1300 m·asl (53.75) whereas the lowest percentage of juice was recorded in the fruits of 700 m·asl (46.69) on 10th November. Beyond 20 November, the level of juice content was found in constant or in decreasing trend. These findings are in corroboration with the findings of (Bhusal, [19]) in mandarin (Bhullar, [25]) in sweet orange (Bakhshi *et al.*, [21]) in sweet orange, (Khokhar and Sharma, [27]) in sweet orange, and (Deka *et al.*, [18]) in Khasi mandarin. Decreasing in juice percentage was directly correlated with fruit weight. The decreasing trends in juice content might be due to catabolism activities in the fruits.

3.7. Peel, Rag, and Seed Content

The percentage weight of peel was recorded low at initial and then gradual increased with the maturity advancement and immediately after peak point of growth it was declined in all the locations and maturity stages. As in **Table 2** the maturity level was advanced with a little increase in peel weight with the corresponding de-

Table 2. Effect on juice, peel, rag, and seed percentage of mandarin fruits at different altitudes and maturity stages.

Altitudes/maturity	Juice (%)	Peel (%)	Rag (%)	Seed (%)
1300 msl				
230 DAF (11 Oct)	39.64	20.6	37.78	1.99
240 DAF (21 Oct)	42.08	24.21	31.1	2.61
250 DAF (31 Oct)	45.83	21.8	30.64	1.73
260 DAF (10 Nov)	50.74	21.22	25.88	2.17
270 DAF (20 Nov)	53.75	22.66	21.9	1.69
280 DAF (30 Nov)	52.69	24.99	20.65	1.66
1000 msl				
230 DAF (11 Oct)	41.7	21.54	34.17	2.59
240 DAF (21 Oct)	45.79	22.67	28.84	2.7
250 DAF (31 Oct)	47.83	21.66	28.12	2.39
260 DAF (10 Nov)	51.66	21.77	24.82	1.75
270 DAF (20 Nov)	55.23	21.63	21.61	1.52
280 DAF (30 Nov)	54.87	22.22	21.45	1.46
700 msl				
230 DAF (11 Oct)	41.65	24.14	31.57	2.63
240 DAF (21 Oct)	42.99	21.41	31.42	4.19
250 DAF (31 Oct)	45.86	22.41	29.52	2.2
260 DAF (10 Nov)	46.69	23.65	27.49	2.17
270 DAF (20 Nov)	46.18	25.73	25.77	2.33
280 DAF (30 Nov)	46.1	25.44	25.89	1.57
LSD (p = 0.05)	4.58	2.73	2.81	0.79

crease in rag percentage. This finding corroborates with the findings of (Bal and Chauhan, [20]) in kinnow mandarin. The peel percentage was found as the lowest in 1300 m·asl (20.60) whereas the highest in 700 m·asl (24.14). The percentage of peel was ranged from (20.60) to (25.75).The percentage of rag was also found significantly declined with the advancement of maturity. The percentage of rag was highest on 11 October (37.78) where as it was recorded (20.65) at the end of the study. Hence it showed that there was changed the juice percentage with declining of rag percentage. The degree of declining in the rag percentage was found much higher in the fruits of 1300 m·asl but lower degree of change was found in the fruits of 700 m·asl. The percentage weight of seed was found low at initial in all altitudes but gradually peaked up simultaneously with fruit weight and then started declined. The percentage of seed was recorded lower in the fruits of higher altitude (1.97) and found highest in the fruits of lower altitude (2.51). (Khokhar and Sharma, [27]) had recorded similar findings in sweet orange. The minimum seed percentage might be due to replacing by the juice sacs in the pulp.

3.8. The Total Soluble Solids (TSS ˚Brix) Content

The Total Soluble Solid (TSS ˚brix) content at different maturity stages of three altitudes 700 m, 1000 m, and 1300 m was recorded and shown in **Table 3**. The TSS was observed as increasing with advancement of maturity in all altitude. In initial stage (230 DAF), TSS was found 6.81, 7.52, and 8.32 ˚Brix respectively in 1300 m·asl, 1000 m·asl, and 700 m·asl altitudes. In initial dates lower altitudes (700 m·asl) had lead in the TSS however; it was overtaken by higher altitude (1300 m·asl) on later date of harvesting (beyond 10 Nov). The TSS was found in wider range at 1300 m (6.81 to 11.63) but 700 m had recorded narrow range (8.32-10.82) over the period of

Table 3. Effect on chemical characteristics of mandarin fruits at different altitudes and maturity stages.

Altitudes/maturity	TSS (˚Brix)	TA (%)	TSS/TA ratio	Vitamin C (mg/100 ml)
1300 msl				
230 DAF (11 Oct)	6.81	2.59	2.65	37.12
240 DAF (21 Oct)	7.49	2.39	3.15	34.64
250 DAF (31 Oct)	8.72	1.49	6.21	33.77
260 DAF (10 Nov)	9.99	1.03	9.76	33.33
270 DAF (20 Nov)	11.05	0.78	14.28	29.43
280 DAF (30 Nov)	11.63	0.66	17.76	27.62
1000 msl				
230 DAF (11 Oct)	7.52	2.39	3.14	34.73
240 DAF (21 Oct)	7.79	2.05	3.92	32.05
250 DAF (31 Oct)	9.37	1.43	7.00	32.56
260 DAF (10 Nov)	10.17	0.98	10.48	32.44
270 DAF (20 Nov)	10.46	0.82	12.78	28.42
280 DAF (30 Nov)	11.05	0.67	16.52	26.16
700 msl				
230 DAF (11 Oct)	8.32	2.15	3.88	33.77
240 DAF (21 Oct)	8.68	1.90	4.82	30.36
250 DAF (31 Oct)	9.99	1.12	8.96	29.66
260 DAF (10 Nov)	10.22	0.94	10.98	29.55
270 DAF (20 Nov)	10.40	0.85	12.29	28.05
280 DAF (30 Nov)	10.82	0.77	14.34	25.41
LSD (P = 0.05)	0.53	0.30	1.82	2.94

study. The maximum Total Soluble Solid (TSS) was found in the 1300 m·asl (11.63) followed by 1000 m·asl (11.05) and 700 m·asl (10.82) at the end of study. These increased trends in the TSS were also recorded by (Deka *et al.*, [8]) in Khasi mandarin, (Mahajan *et al.*, [23]) in mandarin, and (Khokhar and Sharma, [27]) in sweet orange. It was observed that there was significant difference among the treatments. The TSS was accelerated rapidly from 230 Day after flowering (DAF) in all the altitudes and higher TSS content of mandarin fruits harvested at 280 days as compared to those harvested at 270 days after flowering (DAF). On later stage the TSS observed higher due to accumulation of sugars, increased level of dehydration and higher light intensity. After 260 days after flowering TSS was observed in increasing trends in all locations. TSS was found slightly higher (11.63 ˚brix) at 1300 m altitude than lower altitudes due to late maturity and later dryness in the fruits at 1300 m·asl. This finding also corroborates with the finding of (LARC, [28]) in mandarin, (Bhusal, [19]) in mandarin, and (Ghosh, [6]) in mandarin which stated TSS of the orange increases with the increase in altitude at the later part of the fruit maturity.

3.9. Titratable Acidity (TA)

The organic acids mainly citric acids in citrus are the reserve source of energy. The titrable acidity (TA) percentage of the fruits harvested at different maturity stages in three altitudes has been presented in **Table 3**. The acidity was found decreasing with the advancement of the maturity in all altitude. At initial the acidity percentage was recorded higher (2.59) in the fruit of 1300 m·asl altitude followed by 1000 m·asl (2.39) and minimum percentage (2.15) was found in 700 m·asl altitude. At the end of the study, the TA percentage was minimum (0.66) in higher altitude (1300 m·asl) followed by 1000 m·asl (0.67), and found maximum percentage (0.77) in the lower altitude (700 m·asl) at the end of study. These findings were in corroboration with the findings of the (Bal and Chauhan, [20]) in kinnow mandarin, (Bhusal, [19]), and (Bastakoti and Gautam, [29]), (Thapa and Gautam, [30]) in mandarin who reported acidity was decreased gradually as the fruits approached maturity. The decreased acidity in the ripening might be due to rapid utilization of acids in respiration (TCA cycle). An increase in TSS and corresponding decrease in acidity has also been recorded in all the locations. After 10 November onwards the acidity was decreased sharply in 1000 m·asl and 1300 m·asl altitudes as compared to lower altitudes (700 m·asl).

3.10. TSS/Acid Ratio

TSS/acid ratio has been considered to be a reliable index of judging maturity of mandarin. The maturity indices are differing place to place and crop to crop. As in case of mandarin, TSS/acid ratio is more reliable index than rind colour (Ladaniya, [12]). The TSS/acid ratio was recorded in increasing trends with the advancement of the maturity stages. This finding was conformity with the report of (Bal and Chauhan, [20]) and (Jawanda *et al.*, [24]) in kinnow mandarin. From the perusal from the data shown in **Table 3**, the TSS-acid ratio was reached more >9.5 from the 10th November maturity stage in all the altitudes, however, this ratio was observed maximum (10.98) in the fruits of 700 m·asl whereas minimum ratio (9.76) was recorded in the fruits of 1300 m·asl. Beyond this date, the ratio was sharply increased in the fruits of 1300 m·asl than lower altitudes. The increasing of TSS/acid ratio at 1300 m·asl might be due to comparatively sharp increase in TSS and decrease in acidity on later part of the maturity in 1300 m·asl. At the minimum maturity standard (SSC/TA) of 8:1 was found dislike range in Navel orange as set by California Department of Food and Agriculture (Obenland *et al.*, [9]). The maturity indices in Coorg mandarin for main and monsoon crops are recommended as TSS:acid ratio of 13.2 and 9.1 respectively (Ramana *et al.*, [31]). Nagpur mandarins of Ambia crop grown near Nagpur develop minimum 10% TSS and sugar acid ratio 14 after 270 - 280 days from fruit set are quite acceptable (Ladaniya, [32]). (Bose, [33]) has stated that 8:1 TSS-acid ratio was considered to be optimum for marketable fruits. The TSS-acid ratio was recorded highest (17.76) in the fruits of 1300 m·asl followed by 100 m·asl (16.52) and 700 m·asl (14.34) at the end of study. The increased TSS could have been due to further synthesis and accumulation of photosynthates in the fruits on the tree. The loss in acidity was reported to be due to normal respiration and conversion to other metabolities (EI-otmani and Coggins, [34]).

3.11. Ascorbic Acid Content

Ascorbic acid content in the fruits of all the altitudes with their harvesting dates was demonstrated in the **Table 3**. In initial stage, vitamin C was found higher in the fruits of 1300 m altitude (37.12 mg/100ml) whereas lowest quantity was found in the fruits of 700 ma altitudes (33.77 mg/100ml). It was obvious that vitamin C was gradually declined in the fruits at all locations with corresponding date of harvesting. At the end of the study, the vitamin C content was observed maximum (27.62 mg/100 ml) in the fruits of higher altitude (1300 m) and found minimum (25.41 mg/100 ml) in the fruits of lower altitudes (700 m). Vitamin C was recorded decreased level with decreased level of the acidity (**Table 3**). These findings were conformity with the findings of (Bal and Chauhan, [20]) in kinnow mandarin, (Deka et al., [18]) in Khasi mandarin who recorded slightly in decreasing trend. A decrease in ascorbic acid could be due to enzymatic loss of L-ascorbic acid where it is converted to 2-3-dioxy-L-gluconic acid (Mapson, [35]).

4. Conclusion

The study revealed that maturity was dependable to the altitudes and time of harvesting. Generally, 10 days difference in maturity was observed to harvest in each altitude. 30 October for lower altitude, 10 November for middle altitude, and 20 November for higher altitude was found the best date of harvesting for effective marketing, transportation, and storage. Altitude effects on maturity and internal quality of the fruits subsequently in the storage behaviour has been observed. From the above observations 1000 - 1300 m·msl was the best location for mandarin production and 10-20 November was the best period for the mandarin harvesting for optimum maturity.

Acknowledgements

The authors are thankful to Director General of Department of Food Technology and Quality Control (DFTQC) of Ministry of Agricultural Development, and to the chief of postharvest research unit of NARC, Khumaltar, Lalitpur for providing lab facility during the this experiment.

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