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Compositional Differences in Peel and Juice of Cracked and Normal Fruits of Lemon (*Citrus limon* Burm.)

R. Kaur[1*], N. Kaur[1], H. Singh[2], and M. Kaur Sangha[3]

ABSTRACT

Fruit cracking is a predominant physiological disorder of lemon that limits its productivity. The present study aimed to compare the physiological and biochemical traits of cracked and normal fruits of lemon, to understand the cause of fruit cracking and find a viable solution for this disorder. This study was conducted on five-year-old uniform healthy trees grown at fruit research farm, Punjab Agricultural University, Ludhiana, during 2017-2018. Fruits of lemon cracked in different patterns and the cracking peaked due to sudden rainfall and high humidity after a dry spell during the two consecutive years of study. The peel thickness, peel percent and chlorophyll content of the cracked peel was significantly low as compared to the normal ones. Activity of peroxidase and two cell wall degrading enzymes, namely, cellulase and polygalacturonase were higher in cracked peels. Juice content and ascorbic content were low in cracked fruit juice as compared to normal ones. Meanwhile, calcium, potassium and boron content were higher in the normal peel and lower in the cracked peel. A significant positive correlation of fruit cracking incidence with proline, peroxidase, cellulase and polygalacturonase was established, whereas a negative significant correlation was established between fruit cracking percent and peel thickness, calcium, potassium, boron, juice percent and ascorbic acid content. Nutrient deficiency and higher activities of cellulase and polygalacturonase in peel of cracked fruits emerged as the cause of fruit cracking incidence in lemon. Hence, foliar application of calcium, potassium, and boron are recommendable as a remedial measure for prevention of fruit cracking in lemon.

Keywords: Cellulase, Fruit cracking, Nutrient deficiency, Polygalacturonase.

INTRODUCTION

Among Asian countries, India is the largest producer of lemon (*Citrus limon* Burm.); which is cultivated in Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, and Uttar Pradesh. In India, area under cultivation of lime and lemon is 286,000 ha with a production of 3,148,000 tons (FAO, 2018). Fruit cracking is a serious pre-harvest problem that occurs mostly during the cell enlargement or the fruit maturity phase (Li and Chen, 2017). It is not a burst, but a gradual process that varies with fruit varieties and fruit developmental stages. Cracked fruits are more prone to chemical injury and the presence of cracks on the fruits permits the infection by fungus. Cracking facilitates the rapid moisture loss and excessive shriveling, which usually lowers the fruit quality and storage life (Butani *et al*., 2019).

Fruit cracking is a major physiological disorder indicated as a peel meridian fissure that forms from the stylar end and extends till the equatorial zone or beyond it (Sandhu and Bal, 2013). In spite of having high significance, lemon cultivation has not gained upsurge on a commercial scale because of its thin peel and being highly susceptible to fruit

[1] Department of Botany, Punjab Agricultural University, Ludhiana, 141004, India.
[2] Department of Fruit Science, Punjab Agricultural University, Ludhiana, 141004, India.
[3] Department of Biochemistry, Punjab Agricultural University, Ludhiana, 141004, India.
*Corresponding author; e-mail: ravneet-bot@pau.edu

cracking. It is noticeable in almost all the citrus varieties. Besides citrus, fruit cracking, which is referred as fruit creasing or fruit splitting, is also seen in litchi, mango, pomegranate, cherry, apple, guava etc. (Cronje *et al.*, 2011).

The several factors that influence and contribute to fruit cracking in citrus include the pressure induced by the most expeditiously spreading pulp during the process of fruit growth and development resulting in the formation of microcracks in the flavedo that causes initiation of split at the stylar end (Barry and Bower, 1997; Kaur *et al*., 2022). Factors that contribute to the onset of fruit cracking in citrus could be cultural, environmental, morphological and nutrient imbalance. The cultural and environmental factors include irregular water supply, nutrient mis-management, heavy crop load, warm and humid weather conditions (Barry and Bower, 1997). The morphological factors that contribute to fruit cracking are thickness of peel (Holtzhausen, 1981) and its hardness (Li, 2009).

Earlier reports indicated that the enzymatic peeling of citrus fruit exhibited that albedo is efficiently degraded by the activity of enzyme, which acts on polygalacturonic acid and reduces pectins (Pretel *et al*., 2005). Enhanced loss of pectins and cellulose in the cell walls of rind tissue of sweet orange has been associated with fruit creasing (Li *et al*., 2009). We surmise that the estimation of comparative changes in enzymatic activity of normal and the cracked fruit will help in understanding of this disorder. The putative physiology of rind breakdown may be similar to fruit softening and fruit creasing caused by cell wall disassembly (Brummel, 2006). It was hypothesized that creasing may be due to architectural changes in structure of cell wall components, peel thickness, and activities of various enzymes involved in cell wall degradation.

Fruit cracking causes adverse effects on the yield and reduces economic returns to the growers. Cracked fruits further attract insects and pathogens that may cause decay in neighboring trees of the orchard, and to sanitize such orchards, intense labor may be required. Hence, an attempt was made to compare the cracked and normal fruits of lemon on the basis of their physiological and biochemical traits to understand the mechanism of fruit cracking

MATERIALS AND METHODS

The present investigation was carried out at the fruit research farm of Fruit Science Department and Laboratory of Botany Department, Punjab Agricultural University, Ludhiana, during two consecutive years, i.e., 2017-2018. Lemon cv. Punjab Baramasi grafted on rootstock *Citrus jambhiri* Lush. (Rough lemon), and planted during August 2012 at a spacing of 6×3 m were selected as experimental trees. The experiment was conducted on five-years-old uniform healthy trees that were selected randomly in the orchard. A total of thirty trees were marked, which were distributed in five replications, keeping six trees per replication. The irrigation and fertilization schedule of the marked trees was according to the recommended practices given by Package of Practices, Punjab Agricultural University, Ludhiana (Anonymous, 2018). The soil of orchard was deep, well-drained and loamy sand. The studies were performed during the fruiting season, i.e., early April to mid-July of 2017 and 2018, and data presented is an average of two consecutive years. The collection of normal and cracked fruit samples were done separately at peak cracking stage by manual picking of fruits with the help of secateurs. Only freshly cracked fruits were collected by ignoring old, dried, and dropped cracked fruits. Five samples (i.e., normal and cracked separately) from every replication were collected for experimentation.

Pattern of Cracking

The pattern of cracking in the cracked fruits was categorized as radial, transverse, and irregular depending upon the type of fissure as described by Josan (1991).

Fruit Cracking Percent

Total fruits on the tree were counted from first week of April (7 Days After Fruit Set; DAFS) till the date of harvest, i.e., mid-July (105 DAFS) during both the years of study. The number of cracked fruits was counted periodically at weekly interval. The percent of fruit cracking was calculated on the basis of total number of cracked fruits and fruits on the tree at weekly interval by employing the following formula:

$$\text{Fruit cracking percent} = \frac{Number\ of\ cracked\ fruits}{Total\ number\ of\ fruits} \times 100 \quad (1)$$

Physiological Parameters

The peel thickness, peel percent, and juice percent were quantified from normal and cracked fruits. To record peel thickness, the peel of fresh normal and cracked fruits was taken by hand peeling at weekly interval. Peel thickness of normal and cracked fruits was recorded with the help of Vernier's caliper in mm.

To record peel percent, the peels of normal and cracked fruits were removed and weighed. The peel percent was calculated on fresh fruit weight basis by employing the following formula:

$$\text{Peel percent} = \frac{\text{Peel weight}}{\text{Weight of fruit}} \times 100 \quad (2)$$

To calculate juice percent, the fruit weight was recorded followed by extraction of juice and measurement of its weight. The juice percent was calculated on fresh fruit basis.

$$\text{Juice percent} = \frac{\text{Weight of juice (g)}}{\text{Weight of fruit (g)}} \times 100 \quad (3)$$

Biochemical Characteristics

The proline content, activity of peroxidase, cellulose, and polygalacturonase and the nutrient content was analyzed in the peel of cracked and normal fruits. Proline determination was done according to the methods of Bates *et al*. (1973). Peroxidase (POX) (EC 1.11.1.7) activity was assayed by the method provided by Thomas *et al*. (1981). The activity of two cell wall degrading enzymes, namely, cellulase (EC 3.2.1.4) and polygalacturonase (EC 3.2.1.15) were estimated following the methods described by Malik and Singh (1980).

Calcium, potassium, and boron content of peels of both normal and cracked fruits was determined by digesting one gram of each sample in 10 mL of di-acid mixture of nitric acid and perchloric acid in the ratio of 3:1. Potassium content was estimated by the flame photometer as per method described by Chapman and Pratt (1961), while calcium content was determined by atomic absorption spectrophotometer. Boron was determined by Azomethine-H method described by Berger and Truog (1939).

Juice percent and ascorbic acid (vitamin C) content of juice were quantified in normal and cracked fruit juice using the standard methods (AOAC, 1990).

Agro Meteorological Data

The agro meteorological data *viz*., maximum and minimum temperature, relative humidity, rainfall intensity and number of rainy days for two study years was attained from School of Agricultural Meteorology, PAU.

Statistical Analysis

The data was analyzed statistically using Tukey's HSD test. Differences were considered statistically significant at $P \leq 0.05$ using Statistical Analysis Software (SAS) version 9.3 for Windows. Pearson correlation coefficients were generated for establishing a correlation between fruit cracking parameters by using Statistical

Package for the Social Sciences (SPSS) version 16.0 for windows.

RESULTS AND DISCUSSION

Pattern of Cracking

Pattern of cracking in lemon fruit was categorized as radial, transverse, irregular, oblique and combination of radial and transverse cracking (Figure 1). Cracking that initiated at the stylar end of the fruit and extended to the equatorial zone was regarded as 'radial' type of cracking. In 'transverse' cracking, fissure originated between the two ends of fruits. The various kinds of cracking that followed no set pattern were regarded as 'irregular'. The initiation of cracking was observed in the last week of May and first week of June during 2017 and 2018, respectively. The fresh initiation of cracking continued till mid-July during the two years of investigation.

Fruit Cracking (%)

The data on percent fruit cracking on the basis of number of cracked fruits per tree in lemon is presented in Figure 2. During 2017, cracking was initially observed on 22nd May (1.04% fruit cracking), thereafter, an increase in cracking was recorded from 22nd May to 26th June, which declined thereafter. The fruit-cracking peak (17.57%) was recorded on 26th June. During mid-July, new cracking did not appear, only old cracked fruits on the trees were seen, which were infested with insects, pests and fungus. By the end of July, few of the cracked fruits dropped off and cracked fruits were 5.48% only. In our study, cracking was observed to peak on 26th June, which could be due to a sudden rise in the humidity caused by two rainy days after a continued dry spell (Annexure 1).

During 2018, cracking initiated in the first week of June and continued till mid-July. In the first week of June, 2.18% cracking was recorded. Cracking increased continuously from 5th June till 3rd July, it became maximal (18.34%) on 3rd July and declined significantly thereafter. A peak in cracking was possibly due to heavy rainfall and humidity as supported by agro meteorological data (Annexure 1). Through anatomical studies, Kaur *et al*. (2019) reported that fruit cracking in lemon might be due to sudden excessive influx of water

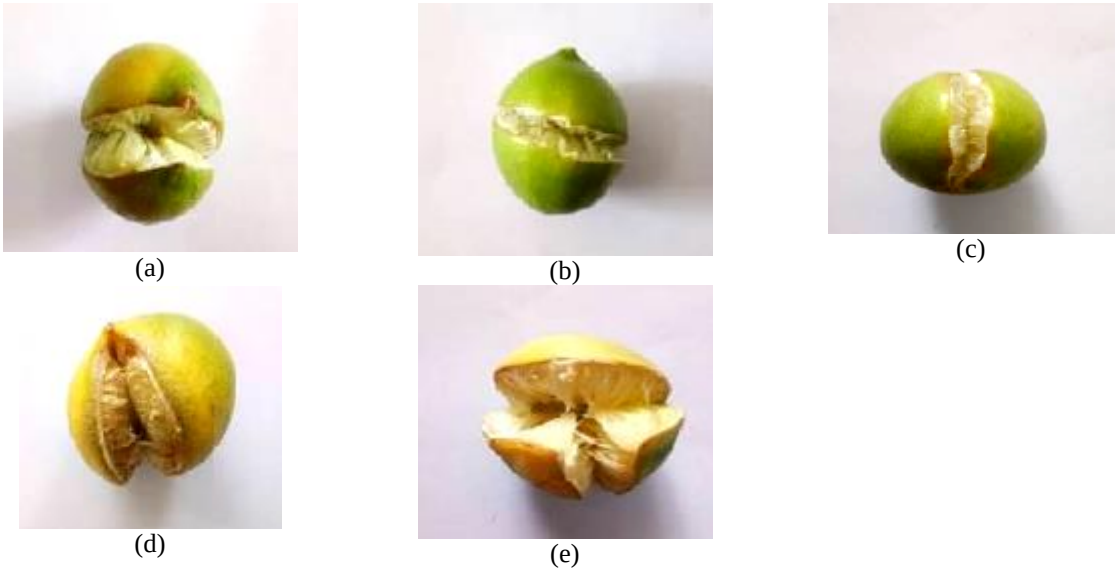


Figure 1. Patterns of cracking: (a) Radial cracking, (b) Transvers cracking, (c) Irregular cracking, (d) Oblique cracking, (e) Combination of radial and transverse cracking.

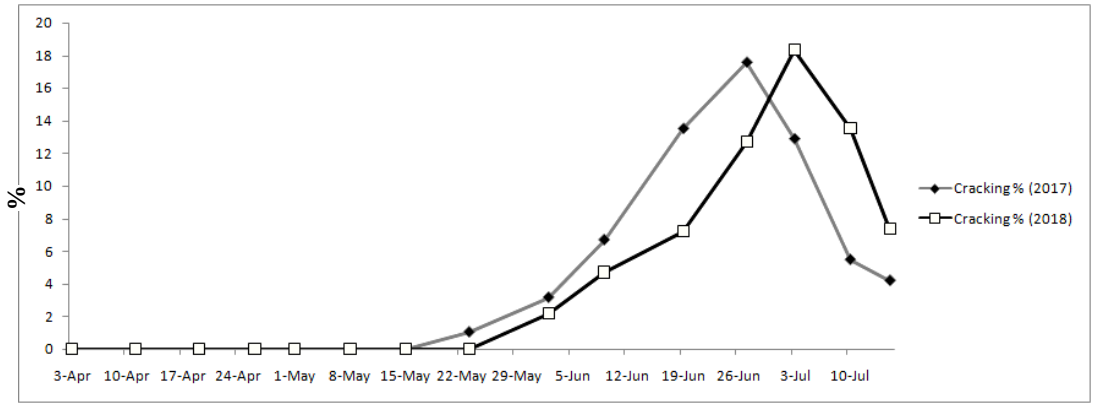


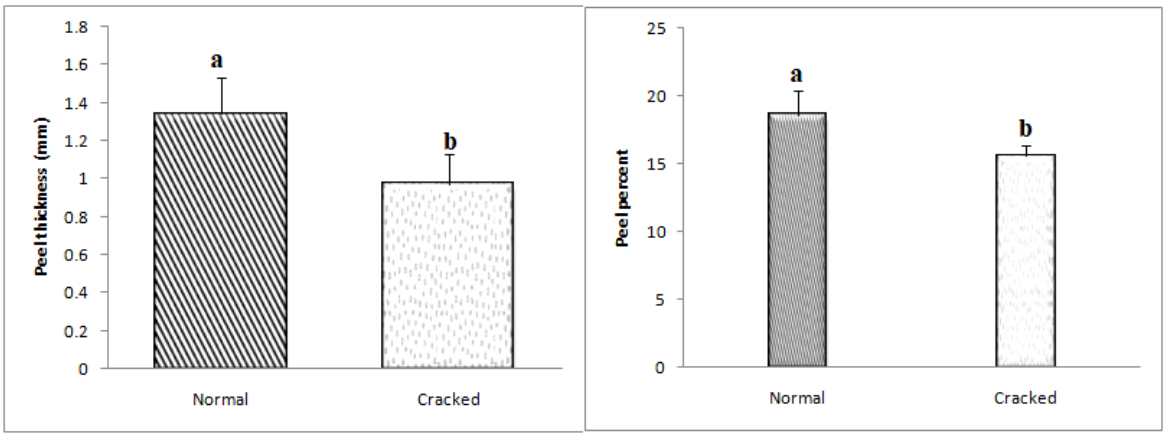
Figure 2. Fruit cracking (%) at weekly interval during 2017 and 2018.

after a continuous low water influx. This irregularity in influx of water creates tension in xylem vessels. The disorganization of xylem tissue due to discontinuity in water transport, followed by pulp expanding, resulted in thinner peels leading to fruit cracking. The disorganization of vascular tissues was also seen in pedicel of cracked fruit, which disrupts the regular transport of water and nutrients to the developing fruit, resulting in fruit cracking. Milad and Shackel (1992) observed similar pattern of fruit cracking in prune and suggested that pre-mature strengthened cells are unable to react to sudden supply of large threshold of water after a period of dry spell; consequently, the pulp expands in volume and exerts large tension on peel, which causes eventual breakdown of tissue and induces microcracks on upper surface of peel, resulting in cracking. Khehra and Bal (2014) reported that fruit cracking in lemon peaked when atmospheric humidity and soil moisture status increased abruptly following onset of monsoon rains. High water supply triggers high incidence of fruit cracking and osmotic potential favors the enhanced absorption of water by fruits, which, in turn, leads to fruit cracking (Lu and Lin 2011).

Physiological Attributes

The data presented in Figures 3-a and -b show, respectively, the peel thickness and peel percent of normal and cracked fruits of lemon. The peel thickness of normal fruits (1.34 mm) was significantly higher compared to cracked fruits (0.97mm). The data on peel percent exhibited a trend similar to the peel thickness and revealed significant variation in peel percent of cracked and normal fruits. Peel percent in normal fruits (18.59%) was higher compared to the cracked fruits (15.55%).

In the present study, fruit cracking was significantly high in fruits having thinner peels and less peel percent. The peel development occurs during stage I and II, while the pulp growth occurs during stage II. Intracellular space of albedo absorbs pressure exerted by the expanding pulp and then the flavedo gets stretched and becomes thinner. Thus, thin flavedo or peel is unable to accommodate the increase in pulp volume making such fruits prone to cracking. This leads to fruit cracking at the stylar end wherever rind is thinner and weaker (Garcia Luis *et al*., 2001). Similar results on fruit cracking were reported earlier by Kaur *et al*. (2019), who suggested that the peels of cracked fruits were rough, coarse and thinner as compared to peels of normal fruits. A negative correlation of fruit cracking with peel thickness has been reported by Ali *et al*. (2000). There are other reports indicating that fruit cracking is associated with peel thickness and, among these, a study made by Li and Chen (2017) reported that citrus cultivars with low fruit



3a 3b

Figure 3. Peel characteristics: (3a) Peel thickness and (3b) Peel percent of normal and cracked fruits of lemon. (Mean values in each bar are significantly different (P≤ 0.05) depicted by alphabet and standard error bars).

cracking rate showed significantly higher fruit peel thickness and hardness compared to cultivars with high fruit cracking rate.

Biochemical Attributes

Fruit Peel: Cellulose is one of the prime constituents of the plant cell wall and this macromolecule can be degraded by plant cellulase, besides this galacturonic acid is the main component of pectin in flavedo of the citrus fruit. In the present study, the activity of cellulase was significantly higher (13.6 µg D-glucose released g^{-1} FW min^{-1}) in peels of cracked fruits compared to the peels of normal fruit (7.17 µg D-glucose released g^{-1} FW min^{-1}) (Figure 4-a). The activity of Polygalacturonase (PG) in the peels of normal and cracked fruits of lemon followed trend similar to cellulase (Figure 4-b). Higher activity of PG was registered with peel of cracked fruits (14.3 µg D-galacturonic acid released g^{-1} FW min^{-1}) compared to the normal fruit peels (9.84 µg D-galacturonic acid released g^{-1} FW min^{-1}). The higher activity of cellulase and polygalacturonase in the albedo and flavedo of cracked fruits causes reduction in cell wall hardening, reduced peel thickness, stiffness and reduced tensile strength of peel, cell wall loosening and crack formation. Li *et al*. (2009) reported a linear correlation of cracking incidence in sweet orange with the activities of polygalacturonase and cellulase in sweet orange cultivars. The present findings are close to the observations made by Saleem *et al*. (2014) in Washington Navel and Navelina sweet orange who reported that albedo of cracked fruit showed significantly higher activity of polygalacturonase than the albedo of normal fruit at the same stage. The upraised activity of polygalacturonase in the albedo and flavedo of cracked fruits compared with normal fruits appear to be associated with the enhanced loss of pectins. This loss of pectin is accompanied by accumulation of starch in the cell walls of the albedo and alteration in mechanical properties of peel that cause cell wall loosening and possibly induces cracks.

The activity of Peroxidase (POD) was significantly higher in peel of cracked [3.51 (ΔA min^{-1} g^{-1}) FW of peel] lemon fruits as compared to peel of normal fruits [2.98 (ΔA min^{-1} g^{-1}) FW of peel] as presented in Figure 4-c. Peroxidase plays an important role in the oxidative degradation of phenolic compounds, which can lead to the production of brown polymers (Tomas and Espin 2001). Robinson (1991) worked out the relationship between POD activity and physiological disorders in vegetables and

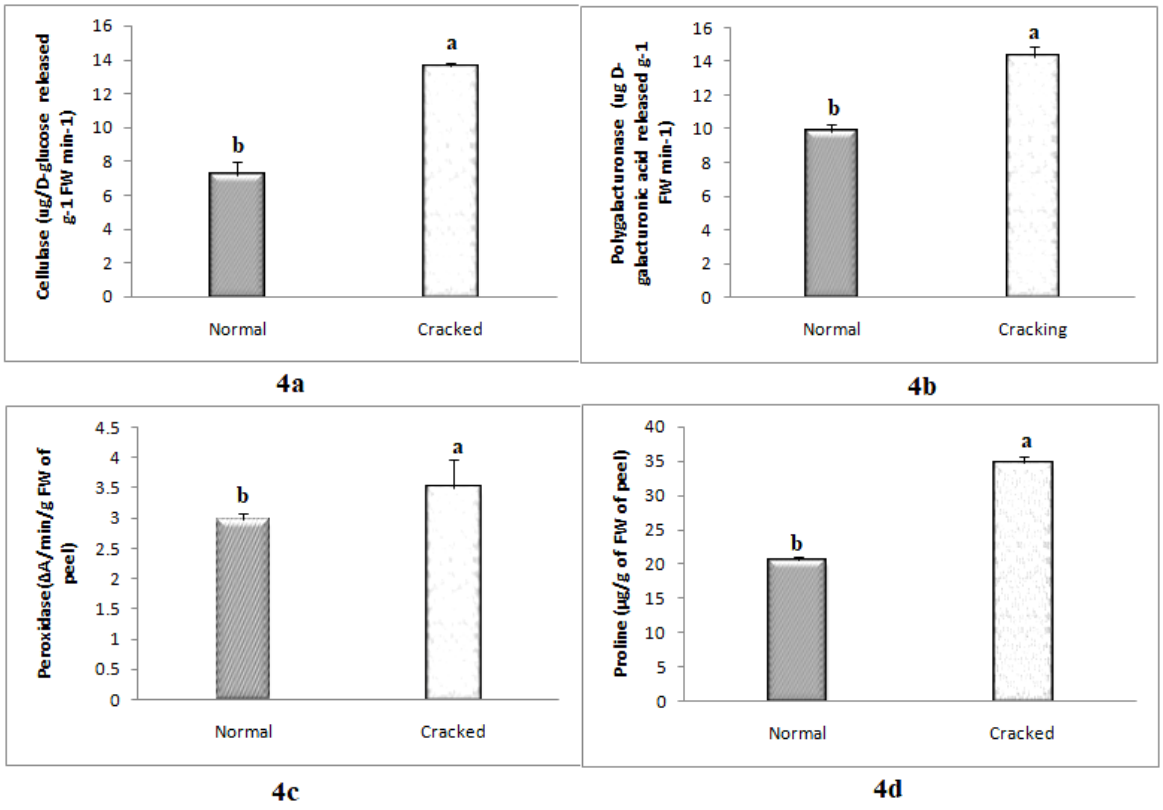


Figure 4. Biochemical attributes of normal and cracked fruit peels of leomn: (4a) Cellulase activity, (4b) Polygalacturonase activity, (4c) Peroxidase acitivy, and (4d) Proline acitivity. (Mean values in each bar are significantly different (P≤ 0.05) depicted by alphabet and standard error bars).

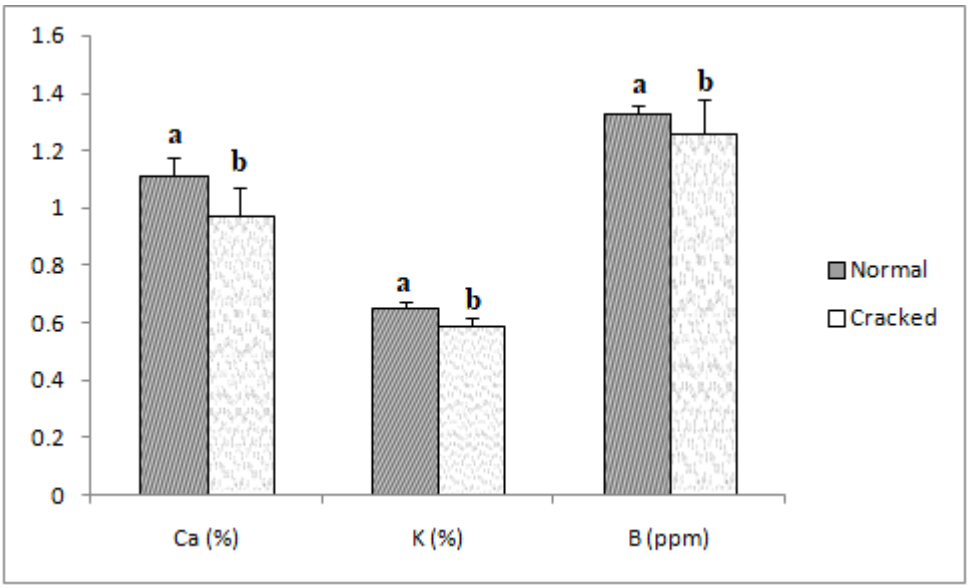


Figure 5. Comparative changes in Calcium (Ca), potassium (K) and Boron (B) content of normal and cracked fruits of lemon. (Mean values in each bar are significantly different (P≤ 0.05) depicted by alphabet and standard error bars).

suggested that POD activity in fruit peel may be linked to the higher cell damage as a response to stress. The modifications of cell wall properties of peel lead to changes in the peel developmental status and its mechanical extensibility that ultimately become a cause of fruit cracking in citrus species.

Proline plays a very important role in metabolism as it protects the plants from stress by its rapid alleviation. Figure 4-d depicts the comparative proline content of peel of normal and cracked lemon fruits and reveals significant variation in peel proline content. Significantly high proline content (34.78 µg g^{-1} of FW of peel) was recorded in cracked peels, whereas it was low in normal fruit peels (20.56 µg g^{-1} of FW of peel). The higher proline content in peels of cracked fruits during the study was possibly due to stress caused by the pressure of cracking. Hayat *et al*. (2012) indicated that a stressful environment results in an overproduction of proline in plants, which, in turn, imparts stress tolerance by maintaining cell turgor or osmotic balance; stabilizing membranes thereby preventing electrolyte leakage and bringing concentrations of Reactive Oxygen Species (ROS) within normal range, thus preventing oxidative burst in plants.

Nutrient content (Ca, K and B) was estimated in dry peels of normal and cracked lemon fruits (Figure 5). Ca and K content were high in the normal fruit peel (1.11 and 0.65% respectively) compared to the cracked peel (0.97 and 0.59% respectively). Similarly, B content was higher in normal (1.33ppm) compared to the cracked peel (1.26 ppm). The deficiency of minerals Ca and K could induce the physiological disorder of peel breakdown and fruit cracking in citrus cultivars.

The findings of the present study depict the role of nutrients in cracking in accordance to Josan *et al.* (1995), who reported lower Ca and K content in peels of cracked fruits of Baramasi lemon. Calcium is an essential component of cell membrane structure and plays a key role in cell division and growth of plant species. The imbalance or deficiency of minerals like Ca could induce physiological disorder like rind breakdown in Nules Clementine (Cronje *et al*., 2011). Potassium plays an important role in growth processes of plant cells and, for cell growth, an optimum K content is essential for maintaining cell osmotic potential and turgor pressure. With a decline in K content in the soil and plant, K from the cytoplasm starts getting utilized, resulting in a decline in the cell growth. Similar reports were made by Morgan *et al*. (2005), who evaluated a split prone cultivar Hamlin orange and reported that an increase in K content concomitant with an increase in peel thickness led to reduction in fruit cracking. Alva *et al*. (2006) reported that peels with low K content were susceptible to cracking due to thinner peels. They further concluded that high K content increased fruit size, smoothness, and peel thickness.

Fruit cracking was negatively correlated with Boron (B) content of fruit peel in the present investigation. Boron is also an important micronutrient involved in cell division, cell wall development, phloem development, and movement of sugars, metabolism of nitrogen and phosphorus, and absorption of salts. Boron treatments permitted higher Ca level associated with pectic compounds and a Ca-strengthened cuticle that can resist higher tension. Wang and Qin (1987) observed a significant difference in B content in normal and cracked fruits and concluded that higher B content reduces fruit cracking to some extent.

Fruit Juice: Data presented in Table 1 depicts the juice percent and ascorbic acid content of juice of normal and cracked fruits of lemon. Juice content was significantly high in normal (35.60%) compared to the cracked fruits (16.13%). Ascorbic acid content in normal fruit juice was also higher than cracked fruits. It varied significantly among normal and cracked fruit juice, being lower in cracked fruits (42.48 mg 100 mL^{-1} of juice) and higher in normal fruit juice (50.54 mg 100 mL^{-1} of juice).

The fruit quality defining parameters *viz.*, juice percent and ascorbic acid content, were

Table 1. Juice quality attributes of normal and cracked fruits of lemon.

Sr No	Fruit type	Juice %	Ascorbic acid (mg 100 mL^{-1} of juice)
1.	Normal	35.6[a]	50.54[a]
2.	Cracked	16.13[b]	42.48[b]
	LSD ($P \leq 0.05$)	8.79	0.22

[a-b] Mean values in the same column having different superscript are significantly different ($P \leq 0.05$).

higher in normal fruits compared to the cracked ones. Low juice per cent in cracked fruit might be due to decrease in moisture content of fruit, as after splitting, hot weather in direct contact with juice vesicles in fruit pulp resulted in dry fruit vesicles and reduced fruit juice. These results were supported by Alva *et al*. (2006), who reported that fruit cracking in citrus cultivars leads to decline in juice content of fruit along with vitamin C content.

Correlation Studies: Pearson correlation coefficients were generated for establishing a correlation between fruit cracking percent, fruit size, peel (peel thickness, peel percent, proline, peroxidase, cellulase, polygalacturonase, calcium, potassium and boron) and juice parameters (juice percent and ascorbic acid content). It is evident from Table 2 that there was a significant positive correlation of fruit cracking with fruit size (r= 0.923**), peel proline (r= 1.000**), peroxidase activity (r= 0.999**), cellulase activity (r= 1.000**) and polygalacturonase activity (r= 1.000**). Significant negative correlation of fruit cracking was established with peel thickness (r = -0.987**), peel percent (r= -0.910**), calcium (r= -0.122**), potassium (r= -0.922**), boron (r= -0.922**), juice percent (r= -0.998**), and ascorbic acid (r= -0.998**) content.

In the current study, we concluded that the fruit cracking incidence was negatively correlated with peel thickness and peel percent. Activity of antioxidant enzyme viz., peroxidase and cell wall degrading enzymes viz., cellulase and polygalacturonase, were positively correlated with fruit cracking, suggesting that alteration in mechanical properties of peel either by lignification or by loss of pectins is associated with fruit cracking. Negative correlation among juice parameters and fruit cracking suggests that fruit cracking results in high economic loss

Table 2. Pearson correlation coefficients among fruit cracking percent, peel and juice parameters.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Fruit cracking percent	1	.923**	-.987**	-.910*	.999**	1.000**	1.000**	1.000**	-.122**	-.922**	-.922**	-.998**	-.998**
2. Fruit Size		1	-.888*	-.816*	.924**	.919**	.922**	.920**	-.144	-.984**	-.707	-.919**	-.918**
3. Peel Thickness			1	.948**	-.983**	-.984**	-.990**	-.990**	.230**	.890*	.938**	.993**	.992**
4. Peel percent				1	-.903*	-.898*	-.917**	-.921**	.415**	.827*	.893*	.932**	.932**
5. Peroxidase					1	.999**	.998**	.999**	-.084**	-.914*	-.925**	-.996**	-.997**
6. Proline						1	.999**	.998**	-.098**	-.921**	-.919**	-.996**	-.996**
7. Cellulase							1	1.000**	-.137**	-.922**	-.924**	-.999**	-.999**
8. Polygalacturonase								1	-.134**	-.919**	-.927**	-.999**	-1.000**
9. Calcium									1	.244	.098	.169	.159
10. Potassium										1	.714	.920**	.918**
11. Boron											1	.927**	.929**
12. Juice percent												1	1.000**
13. Ascorbic acid													1

*Correlation is significant at 0.05 level (2-tailed); **Correlation is significant at 0.01 level (2-tailed).

due to deterioration of fruit quality parameters *viz*., juice percent and ascorbic acid. Correlation of parameters of normal and cracked orange fruit has been established earlier by Sallato *et al*. (2015).

CONCLUSIONS

Rainfall and high humidity after a dry spell enhanced absorption of water by fruits that aggravated the incidence of fruit cracking of lemon. The elevated activities of cell wall degrading enzymes cellulase and polygalacturonase in peel of cracked fruit appear to be associated with the enhanced loss of pectins in the cell wall, consequently, reducing peel thickness and tensile strength of the peel, possibly leading to cell wall loosening and crack formation in lemon. Deficiency of nutrients viz., Ca, K, and B in the peel induces physiological disorder leading to fruit cracking that deteriorates the fruit quality by reduction in juice percent and ascorbic acid content. Nutrient deficiency (Ca, K, and B) and higher activities of cellulase and polygalacturonase in peel of cracked fruit peels may be the underlying cause of cracking in lemon. Foliar spray of calcium, potassium and boron is recommendable as a remedial measure for prevention of fruit cracking in lemon.

ACKNOWLEDGEMENTS

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Annexure 1. Agro meteorological data for the period April to July 2017 and 2018. [a]

Week	Mean temperature (°C)		Mean relative humidity (%)		Mean rainfall intensity (mm)		Number of Rainy days	
	2017	2018	2017	2018	017	2018	2017	2018
April I	26.7	24.8	58	52	00	00	0	1
April II	26.1	27.5	47	51	6.2	00	1	0
April III	23.8	25.6	35	53	00	10.0	0	0
April IV	32.7	27.4	37	41	00	00	0	0
May I	25.6	30.4	34	42	00	15.4	0	0
May II	33.5	29.7	34	39	00	36	0	0
May III	32.5	30.9	37	37	00	00	0	0
May IV	32.7	32.9	41	21	10.0	00	1	0
June I	31.0	34.4	47	35	21.6	00	1	0
June II	33.2	32.9	47	53	26.6	37.8	1	2
June III	32.2	32.9	42	49	5.0	66.8	1	2
June IV	31.5	32.3	64	49	18.8	00	2	0
July I	30.6	30.8	68	58	77.2	37.2	3	0
July II	30.5	29.9	70	73	39.6	52.8	4	2
July III	31.7	31.8	67	69	9.8	64.0	2	0
July IV	31.5	29.7	70	80	25.0	167.8	1	4

[a] (Attained from School of Agricultural Meteorology, PAU).

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تفاوت های مواد ترکیبی در پوست و آب میوه‌های ترک خورده و معمولی لیمو (*Citrus limon* Burm.)

ر. کاعور، ن. کاعور، ه سینگ، و م. کاعور سنگا

چکیده

ترک خوردن میوه یک آشفتگی و اختلال فیزیولوژیکی عمده در لیمو است که بهره وری آن را محدود می کند. هدف این پژوهش مقایسه ویژگی‌های فیزیولوژیکی و بیوشیمیایی میوه‌های ترک‌خورده و معمولی لیموترش، شناخت علت ترک خوردن میوه، و یافتن راه‌حل مناسب برای این اختلال بود. این پژوهش روی درختان سالم ویکنواخت پنج ساله در مزرعه تحقیقاتی میوه، دانشگاه کشاورزی پنجاب، درLudhiana ، طی سال‌های 2017-2018 انجام شد. ترک خوردن میوه های لیموترش به دلیل بارندگی ناگهانی و رطوبت زیاد پس از یک دوره خشکی به اوج خود رسید و لیموها در دو سال مطالعه پیاپی به شکل های مختلف ترک خورد. ضخامت پوست، درصد پوست(peel percent) و محتوای کلروفیل پوست ترک خورده به طور قابل توجهی در مقایسه با پوست معمولی کمتر بود. فعالیت آنزیم پراکسیداز و دو آنزیم تخریب کننده دیواره سلولی به نام سلولاز و پلی گالاکتوروناز در پوست های ترک خورده بیشتر بود. محتوای آب میوه و محتوای آسکوربیک در آب میوه‌های ترک خورده در مقایسه با آب میوه‌های معمولی کمتر بود. همچنین،، محتوای کلسیم، پتاسیم و بور در پوست نرمال بیشتر و در پوست ترک خورده کمتر بود. نیز،همبستگی مثبت و معنی داری بین ترک خوردگی میوه با پرولین، پراکسیداز، سلولاز و پلی گالاکتوروناز مشاهده شد، در حالی که بین درصد ترک خوردگی میوه و ضخامت پوست، کلسیم، پتاسیم، بور، درصد آب میوه و محتوای اسید اسکوربیک همبستگی منفی و معنی داری وجود داشت. کمبود مواد مغذی و فعالیت بیشتر سلولاز و پلی گالاکتوروناز در پوست میوه های ترک خورده عامل بروز ترک خوردگی در میوه لیمو بود. از این رو، برای جلوگیری از ترک خوردن میوه در لیمو، محلول پاشی کلسیم، پتاسیم و بور به عنوان اقدامی درمانی قابل توصیه است.