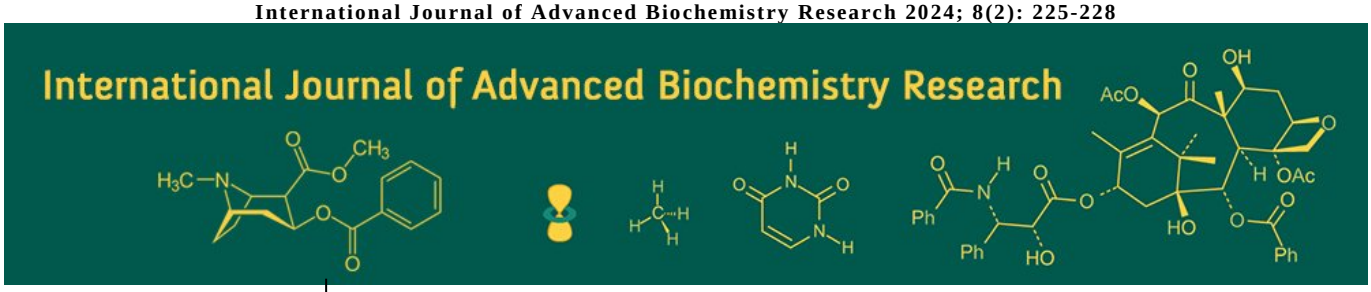

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(2): 225-228
www.biochemjournal.com
Received: 25-12-2023
Accepted: 29-01-2024

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Assessment of post-harvest fruit rots in acid lime

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DOI: https://doi.org/10.33545/26174693.2024.v8.i2c.556

Abstract
Acid lime is the most important fruit crop grown extensively in tropical areas of India. Among different fungal post-harvest rots, Sour rot caused by *Geotrichum candidum* is the most serious one causing up to 24.3% losses in acid lime. Symptoms of the disease appeared initially as soft, watery and slightly discoloured spots on the surface of the fruit rind. During the survey of the post-harvest rots, the incidence of sour rot was recorded up to 24.3%. The extent of post-harvest damage was high at the retailer level (30.3%) and it was maximum in January harvested fruits. At the wholesale and consumer level, the extent of loss is up to 13.9 and 22.1 respectively.

Keywords: Acid lime, post-harvest losses *Geotrichum*, *Aspergillus*, market survey, fruit rots

Introduction
Acid lime (*Citrus aurantifolia* Swingle) is one of the four commercially important citrus fruits grown in the country, besides orange, mandarin and grapefruit. Acid lime crop in India is known to be grown in an area of 2, 75, 000 ha with a production of 27, 63, 570 tonnes and productivity of 10.05 t/ha (www.indiastat.com). In India, acid lime is being cultivated mainly in Maharashtra, Gujarat, Andhra Pradesh, Telangana, Uttarakhand, Bihar, Assam, Karnataka, Madhya Pradesh and other states. It belongs to the botanical family Rutaceae, apart from being used extensively as fresh fruit, it has great demand in the preparation of pickles, food products, and beverages. Due to their positive health benefits, representing an important source of bioactive compounds with high antioxidant activity, such as vitamin C, hydroxycinnamic acids and flavonoids demand was hiked after the coronavirus epidemic. Citrus products and by-products provide the basis for local agricultural industries, which generate employment and raise income, and in many cases, this industry constitutes an important source of foreign revenue for developed and developing countries. Several factors and certain conditions are collectively responsible for fluctuations in citrus production. Selection of rootstock, agronomic practices and management in citrus nurseries and orchards, propagation methods and biotic and abiotic factors contribute their share to some extent to reduced citrus production. Like other commercial crops, several diseases, insect pests and genetic problems affect citrus production. Diseases are one of the major limiting factors for low citrus production and pose a serious threat to the citrus industry. Among these postharvest losses mainly due to diseases (rots) caused 30 and 50% of the total production at different levels of the market. Hence, because of the importance of post-harvest losses we have surveyed different periods of markets in the Nellore district where acid lime is the major economic source of the farming community. In India, survey for the post-harvest spoilage of citrus fruits conducted by various workers revealed that several fungi such as *Penicillium italicum*, *P. digitatum*, *Geotrichum candidum*, *Alternaria alternata*, *A. citri*, *Botryotinia fuckeliana*, *Botryodiplodia theobromae*, and *Glomerella cingulata* are involved in causing different types of rots in this crop (Sharma, 2002; Naqvi, 2004 and Reddy *et al*., 2008) [8]. An average disease severity of 49.63% caused by *Penicillium digitatum* in kinnow fruits recorded under ambient conditions (Alam *et al*. 2016) [1]. Patil *et al*., 2017 [7] worked on a survey of post-harvest *penicillium* mould on sweet oranges during 2015-16 in Tamil Nadu and found that loss due to *penicillium* mould at the wholesale market was 6%, at the retail level was 24%, at the farmers market was 20% and at consumer level was around 2% in locally cultivated fruits, while in rainy season it was recorded 50-60%.

Materials and Methods

To find out the incidence and severity of post-harvest rots of acid lime fruits in the Nellore district, three locations Gudur, Podalakur and Venkatagiri were selected and the survey was conducted at fortnight intervals for four months i.e. from November to February for three years i.e. 2013-14, 2014-15 and 2015-16 at different levels of the market i.e., wholesale, Retail and consumer level. From each place, three samples comprising 100 fruits were observed for disease incidence at each level. The rotten fruits exhibiting different diseases were collected during each visit and brought to the laboratory for isolation and symptomatologic studies. During the survey, we also recorded information about the place of origin, variety, duration of transport and distance travelled. The disease intensity was assessed by using a scale of 0-5.

Category Description

0-No infection
1-0less than 1%
2-1-5% of infection.
3-6-25% infection
4 -26-50% infection
5-more than 50% of infection.

From this, we have calculated the Percent Disease Index (PDI) (Rose, 1974) [10] by using the following formula.

$$\text{PDI: } \frac{\text{The sum total of all individual ratings x 100}}{\text{Total number of fruits graded x Maximum grade}}$$

Results and Discussion

The survey carried out for three years at fortnight intervals from November to February revealed the presence of post-harvest rots, incited due to *Geotrichum*, *penicillium*, *Aspergillus*, *Rhizopus* and others at different levels of the market. (Fig-6) Among different diseases, the incidence of sour rot was predominantly caused by *Geotrichum candidum* (24.3%). The highest incidence of sour rot was recorded in December-January harvested fruits. (Fig-2). At the wholesale marketing stage, the post-harvest losses in acid lime ranged from 7.6 to 13.9% from November to February. Post-harvest losses are peak in December (13.9%) followed by January (11.6%). (Fig-3 & 4) At the retail level fruit spoilage was high because at this stage the fruits are more vulnerable to diseases. The estimated damage recorded was up to 30.3% in January. Sour rot was noticed at a maximum of up to 24.3% of January harvested fruits.) Fig-5) At the consumer level, the magnitude of loss is low when compared to the retail level since the consumers usually keep the fruits for only about 5 days. The extent of losses at the consumer level varied from 11.1 to 22.1%. The maximum loss is due to sour rot (16.1%) in January followed by black mould (5.1%) during December month. (Table-1) (Fig-1) Mandal, 1981 [4] reported from West Bengal as higher as 35% loss due to *Penicillium* species alone in sweet oranges. Naqui and das 1994 [6] surveyed post-harvest losses in Maharashtra. Bali Reddy *et al*., 2008 [8] reported that fungal spoilage was higher in the retail market which was 36.8% in acid lime. Dasgupta and Mandal 1989 [2] described more than 300 parasitic diseases of fruits and vegetables after harvest. Pallavi *et al*., 2014 [11] reported Fungal diseases of 17 selectable fruits and vegetables were studied and their fungal pathogen was observed. Amongst these are *Aspergillus*, *Alternaria* sp., *Fusarium* sp., *Mucor* sp., *Penicillum* sp. *and Rhizopus* sp found to be a major disease-causing organism. Rasool *et al* 2014 [9], the present study found that the *Geotrichum candidum*, *Diplodia natalensis*, *Penicillium* sp, *Trichoderma viride*, *Fusarium* sp., *Alternaria alternata*, *Aspergillus niger*, *Aspergilllus fumigatus*, and *Aspergillus ochraceous* were the fungal pathogens involved in sour rot, stem end rot, green mould, Trichoderma rot, Fusarium rot, black rot, and black mould rot diseases and these were major causes of damage in citrus.

Imansaleh and Roda al-Thani (2019) [3] A total of 73 fungal isolates were isolated and identified, with the highest percentage of *Penicillium (*21.9%) followed by *Rhizopus* (17.8%). Interestingly, many mycotoxins producing and diseases inducing fungi were identified in this study; this includes *Rhizopus*, *Aspergillus*, *Penicillium*, *Alternaria*, *Fusarium*, *Cladosporium*, *Botrytis*, *Geotrichum*, and *Colletotrichum.* Statistical analysis shows that different fruits have significantly different shelf-life and different predispositions for spoilage. Bashir *et al*., 2020 [2] the study revealed that several species of fungi were found to be associated with the spoilage of different types of citrus fruits. However, the most predominant fungi isolated were *Aspergillus niger* with (25.90%) in lime, (21.5%) in lemon and (23.38%) in sweet lemon. However, a total number of 286 fungi were isolated with (40.56%) fungi in lime, followed by lemon with (32.52%) and the least in sweet lemon with (26.92%).

Table 1: Shows Wholesale level, Retail level and Consumer level

	Wholesale level						Retail level						Consumer level					
Month	**G.M**	**B.M**	**Sour rot**	**Anthracnose**	**Soft rot**	**Total**	**G.M**	**B.M**	**Sour rot**	**Anthracnose**	**Soft rot**	**Total**	**G.M**	**B.M**	**Sour rot**	**Anthracnose**	**Soft rot**	**Total**
Nov	0.3	0.3	7.3	-	-	8.0	1.3	5.0	17.6	-	-	22.8	0.1	3.3	8.8	-	0.3	11.1
Dec	-	2.0	11.6	-	-	13.9	-	7.6	18.8	-	-	27.4	1.3	5.1	12.0	-	-	18.5
Jan	-	2.0	9.6	-	-	11.6	1.3	4.6	24.3	-	-	30.3	1.0	4.6	16.1	-	0.1	22.1
Feb	-	0.6	6.9	-	-	7.6	3.3	4.3	11.6	0.1	1.5	20.1	3.0	2.0	10.1	-	-	15.1

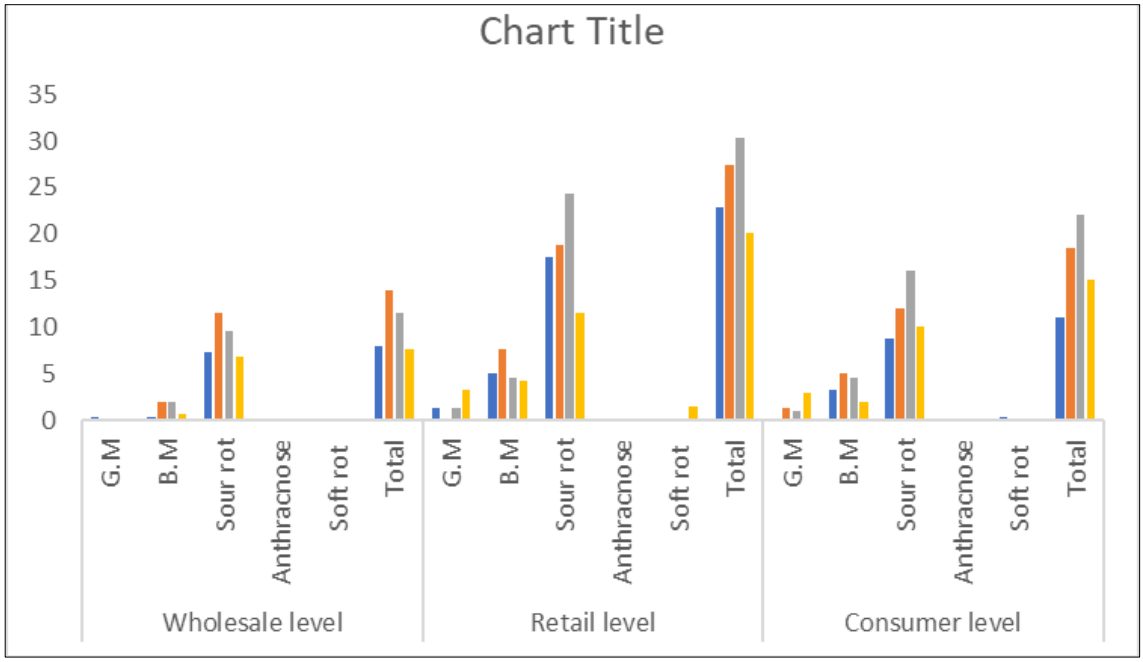

Fig 1: Shows Wholesale level, Retail level and Consumer level

Fig 2: Sour rot affected fruits

Fig 3: Shows *Geotrichum candidum* and *Aspergillus niger*

Fig 4: Whole sale market survey

Fig 5: Retail market survey

Conclusion

Based on results from the present study it is concluded that the infective marketing practices i.e. improper packing, no specific storage facilities, transport and market storage facilities can contribute towards fruit spoilage. so, it was concluded that the providing good storage facilities and avoiding injuries such as cuts during harvest or post-harvest grading and packing we can reduce the post-harvest losses to some extent.

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