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Occurrence and Risk Factors of Fungal Infections in Fruits Traded at the Eldoret Market

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A B S T R A C T

Fruits are highly perishable commodities because of frequent outbreaks of fungal infections, which may affect the shelf life of the fruits in the market resulting in major losses to the farmers The comprehensive survey of market storage and post harvest fungal diseases of some important fruits in Eldoret Market, Kenya was undertaken during January 2012 to May 2012. Fungi were isolated and identified and their risk factors determined in fresh fruits (oranges *Citrus sinerius*, lemons *Citrus limon*, tangerine *Citrus rectaculata*, bananas *Musa* spp., pawpaws *Carica papaya*, avocados *Persia americana*, mangoes *Mangifera indica*, eggfruits *Solanum melanongena*, tomatoes *Lycopersicum esculentum*, pepers *Capsicum* spp.). Slides of diseased tissues were made and observed under light microscope for fungal species. Recurrent sampling from the available market fruits depicted variable intensity of fungal flora. Seven fungal species isolated and identified from the fruits and these were: *Penicillium* spp., *Geotrichum* spp., *Furasium* spp., *Colletotriumchum* spp., *Altenaria* spp., *Rhizopus* spp. and *Gloesporium* spp. Significantly ($p < 0.05$) higher occurrence of *Gloesporium* spp., *Alternaria* spp. and *Penicillium* spp. The prevalence of fungal infections reduced with age sex and levels of education of the respondents. Fruits obtained from the local markets, stored under poor conditions had higher prevalence of fungal infections. This study recommended that traders should provide better storage devices for their fruits to avoid fungal infection.

Introduction

It has been known that fruits constitute commercially and nutritionally important indispensable food commodity. Fruit growing is one of the most important branch of agriculture and consuming plant rich-diets will provide us a milieu of phytochemicals, non-nutritive substances in plants that posses health-protective benefits (Craig, 1997). Fruits play a vital role in human nutrition by supplying the necessary growth factors such as vitamins and essential minerals in human daily diet and that can help to keep a good and normal health. Moreover, previous epidemiological studies have consistently shown that consumption of fruits and vegetables have been associated with reduced risk of chronic diseases, such as cardiovascular diseases and cancers, (Gerber *et al.*, 2002; Kris-Etherton *et al.*, 2002; Serafini *et al.*, 2002) and neuro-degenerative diseases, including Parkinson's and

Alzheimer's diseases (Di Matteo *et al.,* 2003) as well as inflammation and problems caused by cell and cutaneous aging (Ames *et al.,* 1993).

One of the limiting factors that influence the fruits economic value is the relatively short shelf-life caused by pathogens attacked. It is estimated that about 20-25% of the harvested fruits are decayed by pathogens during post-harvest handling even in developed countries (Droby, 2006, Zhu, 2006). Fungal fruit infection may occur during the growing season, harvesting, handling, transport and post-harvest storage and marketing conditions, or after purchasing by the consumer. Spoilage microorganisms can be introduced to the crop on the seed itself, during crop growth in the field, during harvesting and post-harvest handling, or during storage and distribution. Those same types of soil-borne spoilage microbes that occur produce, same spoilage microorganisms that are present on harvesting equipment, on handling equipment in the packinghouse, in the storage facility, and on food contact surfaces throughout the distribution chain. The knowledge of the occurrence and prevalence of fungal contaminants is still restricted since appropriate methods for rapid and long-time monitoring of fruit-borne microorganisms are not available, (Gorny *et al.,* 2002; Burge, 1990). Fruits contain high levels of sugars and nutrients element and their low pH values make them particularly desirable to fungal decays.

The continuous monitoring of fruit-borne biological agents is consequently a necessity, as well for the detection of risks to human health. Numerous research has been conducted that concern, identity and recommends the presence of toxigenic fungi which requires urgent risk management decisions (Saadabi and Al-Amin, 2010). Similarly, previous reports have systematically evaluated the relationship between food-borne fungi and adverse health effects, (Lacey, 1981; Kozak *et al.,* 1979; Macher *et al.,* 1991). Moreover, critical assessment of the fungal types and their relative frequencies in fruits in the market is rarely done. Therefore, the objective of the present study was aimed at examining fruit-borne fungi in traded fruits at the municipal markets of Eldoret in Kenya.

Materials and Methods

Study area

This study was conducted in Eldoret Municipality within Eldoret Town (Fig. 1). It lies at an average altitude of 2100 meters in the high altitude area. The municipality has a population of 400,000 people (KNBS, 2010). The population comprises residents from different Kenyan ethnic groups. Climate within the study areas is strongly influenced by altitude and physical features (escarpments, lakes and volcanic peaks). There is a considerable variation in the climate throughout the area. The areas have maximum temperature that range over the year between 15°C and 28°C with minimum temperature varies between 8°C and 12°C. The mean rainfall is just over 1400 mm annually with the long rains falling between the months of March to May while December to February are dry months, June and July are periods of short rains. The area has almost no permanent rivers flowing across it apart from river Sosiani that flows through the town. The markets within Eldoret Municipality serve approximately 60% of the population. Land use in the area is predominantly small-scale agriculture and livestock husbandry. Agriculture is the predominant land cover in the region where it constitutes some 85% of the land use within the rural areas but in the urban areas, there is considerable commercial activities taking place.

Qualitative data

Research design

This study was based on exploratory survey research design. The design was chosen because it is an efficient method of collecting qualitative data regarding the characteristics of populations, current practices and conditions or needs (Kothari, 2005). This design was adopted in this study in order to capture descriptive data from selected markets and

generalize the findings to the populations from which the sample is selected.

Study population and sample size

A sample of eighty randomly selected fruit traders were used in this study. The eight populations were determined using protocols in Mugenda and Mugenda (1999). The traders in the Eldoret Municipality markets gave correspondence to the questionnaires provided. Samples were also collected from three markets i.e. main market, stage market and Kahoya market.

Instruments for data collection

Both primary and secondary data was used in the study. The method used was a questionnaire as the main tools for data collection. This was guided by the nature of the data to be collected as well as the objectives of the study and time limits. It enabled collection of large data sets within a relatively short time. The questionnaires answered by fruit traders gave views from a larger number of respondents within a short time, thus making it easier to collect relevant information.

Quantitative data

Sample collection

Fresh fruits like, oranges (*Citrus sinerius*), lemons (*Citrus limon*), tangerine (*Citrus rectaculata*), bananas (*Musa* spp.), pawpaws (*Carica papaya*), avocados (*Persia americana*), mangoes (*Mangifera indica*), eggfruits (*Solanum melanongena*), tomatoes (*Lycopersicum esculentum*), pepers (*Capsicum* spp.) were collected from three different markets (Main, Langas and Huruma) in Eldoret Municipality. Samples were transported to the laboratory for identification immediately.

Identification of fungi

Temporary slides of diseased tissues were made and observed under light microscope. Fungi were identified after reference to Barnett and Hunter (1998), Booth (1971), Dix & Webster (1995), Domsch *et al.,* (1980), Dugon (2006), Ellis (1971), Erwin & Ribeiro, (1996) and Nelson *et al.,* (1983).

Isolation of fungi from diseased tissues

After surface sterilization with 5% sodium hypochlorite, a small portion of diseased tissue was cut with the help of a sharp razor and transferred onto Potato dextrose agar (PDA) plates containing penicillin (100000 units/L) and streptomycin (0.2 g/L). After inoculation, Petri dishes were incubated for 7 days at 28°C under 12 hours light and dark conditions. Fungi that grew was identified as described above.

A small portion of mycelium from each fungal colony was transferred into PDA slants. Pure cultures of isolates were identified using the fungal keys provided by Domsch *et al.,* (1980), Sinaga and Quimio (1987), Singh *et al.,* (1991), Quimio and Hanlin (1999) and Quimio (2001). The number of fungal colonies isolated and number of species were determined.

Data analysis

Data collected was analyzed using frequency distributions and cross-tabulation. It was then summarized using descriptive statistics such as inferential statistics using chi-square and correlation analysis using Statistical Package for Social sciences (SPSS version 17.0). The association between fungal species prevalence and risk factors was analyzed using chi-square.

Results and Discussion

Ten fruits were sampled from three markets of Eldoret Municipality and used to characterize fungal infections in the fruits among traders. These fruits included: oranges (*Citrus sinerius*), lemons (*Citrus limon*), tangerine (*Citrus rectaculata*), bananas (*Musa* spp.), pawpaws (*Carica papaya*), avocados (*Persia americana*), mangoes (*Mangifera indica*),

eggfruits (*Solanum melanongena*), tomatoes (*Lycopersicum esculentum*), pepers (*Capsicum* spp.). The description and characteristics of the fungal species identified in fruits provided in Table 1. Based on the visible symptoms, there were seven fungal species isolated and identified from the fruits and these were: *Penicillium* spp., *Geotrichum* spp., *Furasium* spp., *Colletotriumchum* spp., *Altenaria* spp., *Rhizopus* spp. and *Gloesporium* spp.

The fungal species isolated belonged to *Gloesporium* spp., *Alternaria* spp. and *Penicillium* spp (Fig. 2). There were significant differences in the number of occurrence of number and percent abundance of fungal species in the fruits (χ^2 = 19.433, df = 6, p = 0.002). *Penicilium* spp., *Fusarium* spp. occurred in all the fruits sampled in the market (Table 2).

There were significant differences in the occurrence of fungal species in various fruits (χ^2 = 144.787, df = 54, p = 0.0012). Based on the table, tomatoes had the highest prevalence of all the fungal infections while orange and lemon fruits had the lowest occurrence of fungal among the traders.

There were significant effects of age, gender; levels of education, sources of fruits, storage equipment, and duration in the market and storage condition were the main factors that significantly ($p < 0.05$) affected the prevalence of the fungal infections in fruits among the traders in Eldoret Municipality (Table 3). According to the results, prevalence of fungal infections reduced with age; while male traders reported higher prevalence of fungal infections in fruits (Table 3).

Prevalence of fungal infections also reduced in fruits with increasingly levels of education. It was also discerned that traders, who had obtained their fruits from local markets, stored their fruits in buckets, or stored their fruits for over 24 hours and in very poor storage conditions reported higher prevalence of fungal. Losses caused by fungal species are greater than generally realized because the value of fresh fruits increases several-fold while passing from the field to the consumer (Eckert & Sommer, 1967). It was established in this study that seven fungal species in fruits. From the present investigation, it was also observed that areas around Eldoret town are more contaminated with plant pathogenic fungi.

Infected fruit material showed symptoms of blight, leaf spots, white rusts, soft rot, dry rot, powdery mildew and generalized fruit rotting. The presence of these infected fruits in the market may imply low quality of hygiene, careless handling or purchase of already infected fruits.

The species found in the fruits were *Penicillium* spp., *Geotrichum* spp., *Furasium* spp., *Colletotriumchum* spp., *Altenaria* spp., *Rhizopus* spp. and *Gloesporium* spp. These species of pathogens have been reportedly isolated in other food items and found to be the main causes of rotting and post-harvest spoilage of fruits (Domsch *et al.*, 1980; Baiyewu, 2007). Most of the fungal species isolated such as *Gloesporium* spp., *Alternaria* spp. *Penicillium* spp. *Alternaria*, *Fusarium*, *Penicillium*, *Aspergillus*, *Geotrichum* have been reported as common post-harvest fungi (Eckert and Sommer, 1967; Adaskaveg *et al.*, 2002).

Tomatoes had the highest prevalence of all the fungal infections while orange and lemon fruits had the lowest occurrence of fungal among the traders.

Since none of the traders had any refrigeration equipment, chances of mould production might have been reduced as earlier reported by Solomon, 1975; Summerbell, 2000).

Infection of the plants in the field may occur at any time during the growing season. Early infections caused seedling blight and later infections caused foliar blight, stem lesion, vine rot, fruit rot and root and crown rot (Lisker *et al.*, 1993; Lee and Raikel, 1995; Lee *et al.*, 2001; Islam & Babadoost, 2002). Presence of *P. capsici* in fresh fruits of Eldoret markets indicates that the fungus is present in the fields from where the fruits are coming from.

Table.1 Description and characteristics of the fungal species identified in the fruits

Pathogens	Visible symptoms
***Penicillium* spp.**	Soft watery spot, white mycelium developed on the surface, then turns bluish-green fruits disintegrated (decay);Dark sunken spot penetrated skin and reached flesh
***Geotrichum* spp.**	Dark spot (soft rot) on injured fruit; Water soaked spot, spread fruit decayed within 3 days; watery mass oozed from point of inoculation
***Furasium* spp.**	Fruit decayed; pink mycelium appeared; dry rot and small dark symptom spread deeper; fruit disintegrated; Rot spread inside fruit. Tufts of white mycelium appeared Light brown moist rot; becomes darker.
***Colletotriumchum* spp.**	Small dark sunken spots; Black circular spots spread to the flesh; Circular spots with black margins covered with pinkish mass of fungal spores
***Altenaria* spp.**	Brown soft spots with definite margins; Black sunken spots developed into large decayed areas. Dark mycelium appeared whole fruit disintegrated
***Rhizopus* spp.**	Soft watery rot whitish mycelium covered fruit
***Gloesporium* spp.**	Dark spots which spread to form a hardened rot; Skin turned black, rot appeared (covered by pinkish coat)

Table.2 Prevalence of the fungal species in the different fruits traded in the market

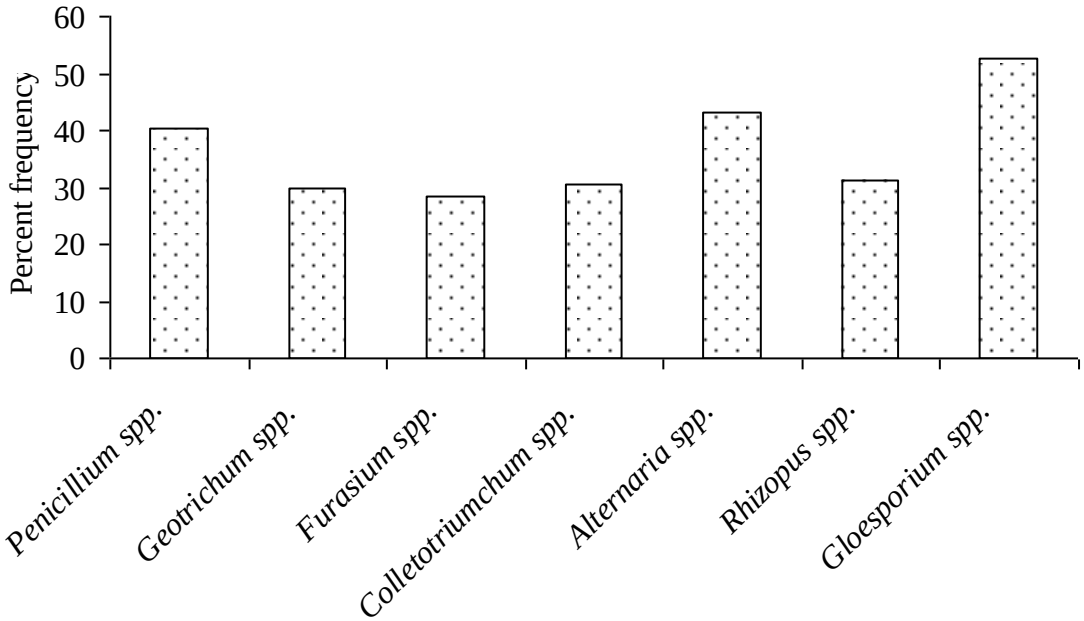
Fruits		Fungal infections						
	N	*Penicillium* spp.	*Geotrichum* spp.	*Furasium* spp.	*Colletotriumchum* spp.	*Altenaria* spp.	*Rhizopus* spp.	***Gloesporium* spp.**
Oranges (*Citrus sinerius*)	20	13.0	0.0	0.0	4.3	0.0	0.0	**4.3**
Lemons (*Citrus limon*)	10	8.7	0.0	7.1	7.1	0.0	0.0	**14.3**
Tangerine (*Citrus rectaculata*)	20	8.7	0.0	4.8	9.5	0.0	0.0	**0.0**
Bananas (*Musa* spp.)	21	4.3	0.0	9.5	9.5	4.8	0.0	**14.3**
Pawpaws (*Carica papaya*)	19	4.3	10.5	15.8	5.3	0.0	10.5	**0.0**
Avocados (*Persia americana*)	8	17.4	12.5	25.0	37.5	12.5	25.0	**12.5**
Mangoes (*Mangifera indica*)	13	8.7	30.8	15.4	7.7	30.8	15.4	**7.7**
Eggfruits (*Solanum melanongena*)	7	13.0	28.6	71.4	28.6	14.3	14.3	**28.6**
Tomatoes (*Lycopersicum esculentum*)	21	26.1	33.3	42.9	28.6	47.6	28.6	**19.0**
***Capsicum* spp.**	**11**	**4.3**	**18.2**	**0.0**	**18.2**	**9.1**	**9.1**	**27.3**

Table.3 Socio-economic and market oriented factors affecting the prevalence of fungal infections among traders in Eldoret Municipality. Numbers marked with asterisk has significantly different prevalence of fungal infections.

Attributes	Frequency	N	% frequency	Prevalence of fungal infections	χ^2	P-value
Age*	<18	12	7	58.3	23.447	0.0001
	18-35	32	13	40.6		
	36-55	26	7	26.9		
	> 55	10	2	20.0		
Gender*	Male	23	10	43.5	33.997	0.0000
	Female	57	17	29.8		
Levels of education*	None	8	5	62.5	14.211	0.0001
	Primary	24	14	58.3		
	Secondary	39	18	46.2		
	College	7	1	14.3		
	University	2	0	0.0		
Income levels	< 1500	3	1	33.3	5.228	0.5401
	1501-5000	3	1	33.3		
	5001-10000	22	8	36.4		
	10001-20000	42	16	38.1		
	> 20000	10	4	40.0		
Sources of fruits*	Local	5	3	60.0	17.235	0.0126
	Imported	7	2	28.6		
	Other traders	51	17	33.3		
	Farmers	17	4	23.5		
Storage equipment*	Crates	43	6	14.0	83.236	0.0000
	Sacks	23	6	26.1		
	Nets	10	3	30.0		
	Buckets	4	3	75.0		
Duration in the market*	< 6 hours	11	1	9.1	67.232	0.0000
	6-12 hours	36	11	30.6		
	13-24 hours	27	11	40.7		
	> 24 hours	6	4	66.7		
Storage conditions*	Very poor	19	11	57.9	57.231	0.0000
	Poor	36	21	58.3		
	Moderate	17	3	17.6		
	Good	8	1	12.5		

Fig.1 Map of Kenya showing the location of the study area

Fig.2 Number of species representing different fungal groups at Eldoret market during the study.



Prevalence of fungal infections reduced with age of the fruit trader; while male traders reported higher prevalence of fungal infections in fruits indicating male may have lower health consciousness than female. Prevalence of fungal infections also reduced in fruits with increasingly levels of education of the sellers indicating that levels of education may influence the levels of hygienic conditions. These results concur with those of Machado and Maraci (1999).

It is more likely that traders with high level of education provide better sanitation condition. It was also discerned that traders, who had obtained their fruits from local markets, stored their fruits in buckets, had stored their fruits for over 24 hours and in very poor storage conditions reported higher prevalence of fungal.

The pathogen infects fruits during prolonged periods of heavy rainfall and high humidity, especially when plants are over-crowded or overfertilized with nitrogen (Shannon, 1989). Fruit rot can occur from the time of fruit set until harvest (Pavón *et al.*, 2007). In Eldoret, spraying of water on fruits during marketing may provide an excellent opportunity for spread of *fusarium* rot. Minimizing post-harvest losses of food that has already been produced is more sustainable and environmentally relevant than increasing production areas to compensate for these losses.

There is also paucity of information on the occurrence of fungal infection in the environment, human and animal infections in Eldoret Municipality. Therefore this may stem from caused fungal pathogens that may be in the fruits and likely to increase fungal infections to the local traders.

Based on the visible symptoms, there were seven fungal species isolated and identified from the fruits. Most of the fungal species isolated belonged to *Gloesporium* spp., *Alternaria* spp. and *Penicillium* spp. There were significant differences in the occurrence of fungal species in the fruits. The prevalence of fungal infections reduced with age; while male traders reported higher prevalence of fungal infections in fruits. Prevalence of fungal infections also reduced in fruits with education levels of the fruit traders.

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