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Fungi associated with the spoilage of berry and their reaction to electromagnetic field

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Fungi responsible for the spoilage of some berry, namely pawpaw (*Carica papaya*), sweet orange (*Citrus sinensis*), banana (*Musa acuminata*), garden egg (*Solanum melongena*), lemon (*Citrus limoni*), and tangelo (*Citrus tangelo*) with respect to their control using electromagnetic field were investigated. Fungi isolated include the genera of *Aspergillus, Penicillium, Rhizopus, Articulospora, Gonatobotryum, Varicosporium, Trichoderma, Blastomyces, Fusarium, Pleurothecium* and yeast, *Saccharomyces*. The fungal isolates were treated by exposure to electromagnetic field strength generated at voltage of 7, 10, and 13 V for periods of 0, 15, 30, 45, and 60 min, respectively. Growth of the fungal isolates was inhibited by the electromagnetic field with the inhibitory effect becoming more pronounced with increase in the field intensity and period of exposure. Apparently, healthy fruits were exposed to the highest electromagnetic field generated (13 V) for maximum time of exposure used (60 min). Proximate and mineral analyses of the treated and untreated fruits revealed that electromagnetic field wave has no negative or adverse effects on the nutrient components of the fruits. Therefore, electromagnetic field wave can be used in controlling spoilage fungi, thereby increasing the shelf life of fruits.

Key words: Berry, electromagnetic field, spoilage, fungi, voltage.

INTRODUCTION

Food spoilage refers to various changes in which the food becomes less palatable or even toxic to consumers; these changes may be accompanied by alterations in taste, smell, appearance or texture. Numerous microbial defects of agricultural crops are characterized by the types of microorganism responsible for their deterioration (Akinmusire, 2011). The process of infection in case of fungal invasion involves the development of fungal penetrating structure and colonization of fungi is a critical phase in the microbial spoilage of post harvested fruits involving the ability of the fungi to establish itself within the host and the magnitude of symptoms of the induced disease is a reflection of the extent of colonization (Chuku et al., 2008). Generally, spoilage fungi are considered toxigenic or pathogenic. Toxigenic fungi have been isolated from spoiling fruits (Tournas and Stack, 2001). During refrigeration, some moulds may produce mycotoxins compounds which are capable of inducing mycotoxicoses in man following ingestion or inhalation (Tournas and Stack, 2001; Effiuvwevwere, 2000). Pathogenic fungi, on the other hand, could cause infections or allergies (Monso, 2004). *Aspergillus* species are known to produce toxic metabolites that are hazardous to human and animal health (Akinmusire, 2011; Petzinger and Weidenbach, 2002).

Fruits and vegetables are vital sources of nutrients to human beings. They give the body the necessary vitamins, fats, minerals, and oil in the right proportion for human growth and development. Fruits and vegetables, however, have serious challenges to their existence. These include changes in climatic condition, pest, inadequate rainfall, and fungal attack. Over the years, there has been an increase in the need to identify and isolate the fungi associated with their spoilage as a way of finding a means of controlling it.

Non-thermal food processing techniques are receiving considerable attention, because of their potential for quality and safety improvement of food (Jarupan and Mohammad, 2008), and effects of electromagnetic field on living systems remains controversial (Roha and

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Mohammad, 2005). Investigations of how magnetic and electric fields affect living organisms at the molecular level have revealed impacts on the biological functions of organisms via changes in the concentration of hormones, activity of enzymes, transport of ions by the cell membrane or changes in the synthesis or transcription of DNA (Strasak et al., 2002). Preliminary studies have suggested that the application of electric and electromagnetic fields are potentially useful methods of non thermal decontamination (Onuegbu, 2002). The purpose of the current investigation is to isolate and identify some spoilage fungi of berry and study the reactions of the fungal isolates when exposed to electromagnetic field.

MATERIALS AND METHODS

Collection of fruit samples

A total number of 6 different types of fruits (three per type) referred to as berry, including pawpaw (*Carica papaya*), sweet orange (*Citrus sinensis*), banana (*Musa acuminata*), garden egg (*Solanum melongena*), lemon (*Citrus limoni*), and tangelo (*Citrus tangelo*) were collected; each of these fruits occupies 16.67% of the total number of fruits collected.

Isolation of spoilage fungi

The fruits obtained were left on the open bench in the laboratory to undergo natural spoilage at ambient temperature (27 ± 2°C). The spoilt areas in and out of the fruits were then swabbed using sterile swab stick and inoculated unto freshly prepared Sauboraud dextrose agar (SDA) and potato dextrose agar (PDA) plates. The inoculated plates were incubated at 25°C for 3 to 5 days, and were observed for fungal growth and later subcultured. Pure isolates of fungi obtained were identified according to the methods of Olutiola et al. (2000) and Barnett and Hunter (1998).

Reinoculation of healthy fruits with pure fungal isolates

The pure culture of the identified fungi was individually reinoculated into healthy fruits as applicable, and the symptoms were compared with the original. This procedure was carried out using the Koch's postulate. This was done to ascertain that the inoculated fungi were responsible for spoilage in their respective fruits.

Treatment of isolates with electromagnetic field

An electric circuit that generated the electromagnetic field wave used for this research work was designed and constructed at the Department of Physics, Federal University of Technology, Akure, Nigeria. The electromagnetic field pulse was generated from solenoid coil of hundreds of turns of copper wire. The coil was connected across a voltage source of about 15 V which induced magnetic field around the coil. The intensity of the field was varied through the variable resistor of 10 k and the timing circuit was wired with 555 timer integrated circuit (IC) as an Astable multivibrator. Triac, a high current switching device was employed to control the flow of current through the coil. The whole circuitry was cased in a locally fabricated Perspex case which served as a guide for the wave. A hole was created through which the wave was focused on the sample. Isolates from the stock culture were transferred unto freshly prepared plates and afterwards multiplied in liquid nutrient medium (broth). From every breed, 1 ml inoculum was taken and introduced into 9 ml freshly prepared broth in test tubes. Then, the test tubes were treated with electromagnetic field generated at voltage of 7, 10, and 13 V for 0, 15, 30, 45, and 60 min, respectively. Non-treated isolates were taken as control so as to allow for comparism the spore count of fungal isolates exposed to electromagnetic field and those which were not exposed. All treatments were in triplicates.

Plating of treated isolates

Following the treatment of isolates with electromagnetic field pulses, the isolates were inoculated on petri dishes containing selected medium and incubated at 25°C for 3 to 5 days. Each fungal isolate from specific fruit were made in three replicates and were exposed to each field strength for each specific period of exposure. After the incubation period, the fungal spores were counted to determine the effect of electromagnetic field wave on the number of spores using the New Improved Neuber Haemacytometer (Profondeur, 2010 Model; Superior Marienfeld Germany, Ref.: 0630010, Lot: 15878802).

Treatment of apparently healthy fruits with electromagnetic field

Each of the fruits sample used for the study was exposed to the electromagnetic field generated at voltage of 13 V, being the highest field generated for the maximum period of exposure used to ascertain the effect of electromagnetic field on some of the nutrient components of the fruits. The highest field and maximum time were used, because maximum inhibitory effect was seen at this strength. The fruits were treated in triplicates. Proximate and mineral analyses were carried out on treated and untreated fruits according to AOAC (2006).

Statistical analysis of data

Data obtained were analyzed using the Statistical Package for the Social Sciences, Windows 7, version 14 (SPSS Inc., Chicago, IL, USA) and means were separated using Duncan's New Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Table 1 shows the various spoilage fungi isolated from each of the selected fruits. A total of thirteen different moulds and one yeast were isolated from the fruits, while Table 2 shows the percentage of occurrence of each of the fungal isolates in the fruits with *Aspergillus niger* and *Penicillium italicum* being the most occurring fungal isolates, while the least occurring fungal isolates were *Penicillium chrysogenum*, *Pleurothecium recurvatum, Rhizopus stolonifer, Fusarium oxysporum*, and *Varicosporium elodae*.

The findings of this work showed that a total of 13 fungal species and 1 yeast were obtained from 6 different fruits (Tables 1 and 2). This is an indication that fungi are potential spoilage organisms of fruits which is in accordance with the findings of Akinmusire (2011) who

Table 1. Fungi isolated from selected fruits.

S/N	Fruit	Fungal isolate
1	Pawpaw (*Carica papaya*)	*A. niger, A. inflata, Gonatobotryum apiculatum, P. italicum, Aspergillus fumigatus, V. elodea*
2	Sweet orange (*Citrus sinensis*)	*A. niger, A. inflata, P. italicum, S. cerevisiae, B. dermatitidis, Trichoderma viride*
3	Banana (*Musa acuminata*)	*A. fumigatus, P. chrysogenum, F. oxysporum*
5	Garden egg (*Solanum melongena*)	*A. flavus, G. apiculatum, R. stolonifer*
6	Lemon (*Citrus limoni*)	*A. niger, A. flavus, P. italicum, T. viride*
12	Tangelo (*Citrus tangelo*)	*S. cerevisiae, B. dermatitidis, Pleurothecium recurvatum, P. italicum*

Table 2. Occurrence of fungal isolates in fruits.

Fungal isolates	Pawpaw	Sweet orange	Banana	Garden egg	Lemon	Tangelo	%
A. niger	+	+	-	-	+	-	12
A. fumigates	+	-	+	-	-	-	8
A. flavus	-	-	-	+	+	-	8
R. stolonifer	-	-	-	+	-	-	4
A. inflata	+	+	-	-	-	-	8
G. apiculatum	+	-	-	+	-	-	8
V. elodea	+	-	-	-	-	-	4
P. chrysogenum	-	-	+	-	-	-	4
P. italicum	+	+	-	-	+	-	12
P. recurvatum	-	-	-	-	-	+	4
B. dermatitidis	-	+	-	-	-	+	8
F. oxysporum	-	-	+	-	-	-	4
T. viride	-	+	-	-	+	-	8
S. cerevisiae	-	+	-	-	-	+	8

+ = Present, - = Absent.

reported that the prevalence of fungi as the spoilage organism of fruits may be due to a wide range of factors encountered at each stage of handling from pre-harvest to consumption. This is also related to the physiological and physical conditions of the fruits as well as the extrinsic parameters to which they are subjected. Thus, the low pH and moisture content of the fruits make them more prone to fungal spoilage. Efiuvwevwere (2000) also reported that high moisture and relative humidity leads to greater fungal growth in agricultural produce resulting in low storability of fruits and vegetables.

The fungi found to be associated with the spoilage of pawpaw were *A. niger*, *Aspergillus. fumigatus*, and *P. italicum*. Akinmusire (2011) reported that *Aspergillus flavus*, which is the same genus with those isolated from pawpaw in this study, is responsible for sunken spots in pawpaw. *A. niger*, *Articulospora inflata*, and *P. italicum* were spoilage fungi isolated from sweet orange; this agrees with the work of Nijis et al. (1997). They reported that *Aspergillus* species is the predominant organism associated with the spoilage of oranges, while Bali et al. (2008) reported *A. niger* and *Penicillium digitatum* as post-harvest spoilage organism of oranges. *F. oxysporum* isolated from banana agrees with the studies of Rashad et al. (2011) where the fungi were implicated as a spoilage organism of banana (Table 3).

In all the fungal isolates, the highest inhibitory effect was seen at electromagnetic field generated at 13 V, especially when exposed for 60 min (Table 4). One of the probable explanations of the effect of electromagnetic field on the fungal isolates might be due to the denaturing effect of EMF on the metabolic activity of the cells. It could also be as a result of the rotating electric field formed by the variable magnetic field. This finding correlates with the work of Pol et al. (2000), who observed that pulsed-electric field treatment, enhanced the bactericidal action of nisin against *Bacillus cereus* with possible changes in the pores of the cytoplasmic membrane.

The electromagnetic field treatment in most cases significantly reduced the growth of the fungi as reflected in their spore count (Figures 1 to 6) when compared with the control. These results are in agreement with the findings of Gaskova et al. (1996) who observed that

Table 3. Percentage reduction of isolated fungi from different fruits.

Fruit	Isolates	15 min (7 V)	30 min (7 V)	45 min (7 V)	60 min (7 V)	15 min (10 V)	30 min (10 V)	45 min (10 V)	60 min (10 V)	15 min (13 V)	30 min (13 V)	45 min (13 V)	60 min (13 V)	Control
Pawpaw (*C. papaya*)	*A. fumigatus*	5.0 ± 1.67	14.9±4.30	20.4±3.42	43.6±3.38	1.7 ± 1.67	13.8 ± 3.43	24.3±6.87	42.5±2.24	13.8±4.04	22.7 ± 4.35	8.8 ± 1.88	47.5 ± 4.62	100
	A. niger	1.9 ± 0.51	4.2 ± 0.30	11.5±0.09	38.1±0.31	2.7 ± 0.12	5.8 ± 0.29	15.2±0.77	39.7±0.76	9.6 ± 0.73	15.4 ± 0.15	38.8 ± 0.54	46.2 ± 1.55	100
	G. apiculatum	0.7 ± 0.12	6.6 ± 0.27	9.9 ± 0.18	35.0 ± 0.12	3.2 ± 0.12	7.1 ± 0.17	20.4±0.09	35.1±0.82	19.4±0.41	22.9 ± 0.33	39.8 ± 0.38	51.5 ± 0.09	100
	V. elodea	35.8±1.11	51.4±0.84	55.9±1.61	72.6 ± 0.83	45.7±1.20	57.3 ± 0.63	64.8±1.22	78.0±0.71	51.6±1.15	58.4 ± 1.39	71.7 ± 1.47	80.2 ± 0.69	100
Sweet orange (*C. sinensis*)	*A. niger*	10.3±1.75	12.1±0.20	24.9±2.80	41.6 ± 1.72	14.0±0.76	19.7 ± 0.29	31.7±0.85	49.1±0.82	19.9±0.67	25.7 ± 0.15	36.7 ± 0.40	52.4 ± 0.47	100
	S. cerevisiae	16.3±7.00	27.0±4.45	36.2±3.76	40.0 ± 2.59	36.9±4.36	40.7 ± 2.13	55.9±1.38	66.1±0.85	43.9±3.51	58.2 ± 2.50	68.4 ± 4.17	76.4 ± 0.77	100
	T. viride	8.4 ± 2.10	15.2±1.37	28.1±1.56	34.7 ± 1.87	11.9±1.77	17.5 ± 1.33	26.9±2.87	39.0±0.78	23.0±2.21	28.2 ± 1.92	38.7 ± 0.85	51.5 ± 1.32	100
Banana (*M. acuminata*)	*A. fumigatus*	28.1±3.13	39.0±0.44	49.3±3.20	59.6 ± 1.84	33.8±2.49	40.1 ± 1.55	53.5±1.81	63.4±1.23	38.0±1.23	41.5 ± 1.33	57.3 ± 1.56	65.3 ± 2.38	100
	F. oxysporum	33.3±1.57	41.6±0.82	66.8±0.61	73.8 ± 0.81	37.3±1.22	43.3 ± 1.17	70.9±1.08	75.7±1.22	45.7±1.32	56.7 ± 1.81	75.5 ± 0.73	84.3 ± 0.73	100
	P. chrysogenum	23.1±0.11	28.8±0.47	58.8±0.67	70.2 ± 0.28	27.5±1.04	29.5 ± 0.38	63.1±0.35	71.0±0.39	28.7±0.40	29.9 ± 0.26	66.3 ± 0.35	71.3 ± 0.23	100
Garden egg (*S. melongena*)	*A. flavus*	33.3±0.11	38.6±0.18	45.3±1.00	48.2 ± 0.41	35.0±1.16^{c}	39.3 ± 0.47	47.6±0.60	49.8±0.80	38.0±1.08	45.3 ± 1.00	51.0 ± 1.10	52.6±0.77	100
	G. apiculatum	15.7±0.40	18.1±0.11	40.8±0.13	42.1 ± 0.10	17.0±0.19^{b}	18.6 ± 0.46	41.7±0.44	42.8±0.24	26.0±0.45	40.8 ± 0.13	42.8 ± 0.17	44.7 ± 0.50	100
	R. stolonifer	2.1 ± 0.24	5.6 ± 0.21	26.8±0.17	32.8 ± 0.70	5.1±0.19^{a}	9.0 ± 0.72	30.4±0.47	35.6±0.57	12.1±1.01	26.8 ± 0.17	40.3 ± 0.48	46.7 ± 1.61	100
Lemon (*C. limoni*)	*A. flavus*	30.4±0.83	34.3±0.42	40.1±0.17	45.3 ± 1.65	33.7±0.72	36.1 ± 0.42	43.7±0.61	45.9±0.39	41.8±0.86	40.1 ± 0.17	50.1 ± 0.69	54.8 ± 0.44	100
	A. niger	12.0±1.31	16.6±1.05	29.5±1.16	34.9 ± 0.78	15.3±1.87	18.3 ± 1.17	32.8±0.82	35.1±0.77	19.3±1.80	29.5 ± 1.16	31.2 ± 1.18	41.0 ± 1.99	100
	T. viride	8.4 ± 2.09	15.2±1.37	28.1±1.56	34.7±1.87	11.9±1.77	17.5 ± 1.33	26.9±2.87	39.0±0.78	23.0±2.21	28.1 ± 1.56	38.7 ± 0.85	51.5 ± 1.31	100
Tangelo (C. tangelo)	*P. recurvatum*	22.7±0.47	32.4±1.93	39.7±1.45	62.5 ± 0.65	34.6 ±1.60	46.0 ± 1.50	55.2±1.90	65.5±2.06	57.9±1.13	39.7 ± 1.45	79.7 ± 1.60	81.9 ± 1.04	100
	S. cerevisiae	8.5 ± 3.80	7.6 ± 2.08	15.3±1.91	22.4 ± 1.28	14.4 ±1.21	22.9 ± 1.53	27.7±0.88	40.5±0.52	16.1±0.62	15.3 ± 1.91	41.9 ± 0.29	48.5 ± 1.35	100

Values are mean ± standard deviation (SD) of replicates (n = 3). Reduction = ((control – period of exposure) / control) × 100.

studies with *Saccharomyces cerevisiae* showed that the susceptibility of actively growing cells to pulsed electric field (PEF) also occurs with yeast cells. It was discovered that increase in the intensity of the electromagnetic field wave decreased the growth of the fungal isolates as revealed by the reduction in spore counts. Mizuno and Hori (1991) and Qin et al. (1994, 1995) reported that various inactivation levels of *S. cerevisiae* have been achieved in foods and food models using varieties of PEF chambers and experimental conditions.

The results of this investigation also revealed that increased duration of exposure of fungi to electromagnetic field resulted in the reduction of most of the fungal isolates as their spore count showed a decrease over those which were not exposed. Moulder (2002) discovered that the period of exposure of the cells of microorganisms to electromagnetic field plays an important role in the production of the biological effect which can cause desirable changes in the cells of the organisms.

To some of the fungal isolates such as *P. italicum*, *A. inflata*, and *Blastomyces dermatitidis* exposure to electromagnetic wave has stimulatory effect, because an increase in the fungal spores

Table 4. Comparison of the percentage reduction of spore numbers (sfu/ml) of fungal isolates after treatment with 13 V electromagnetic field for different periods of exposure of isolates from pawpaw.

Duration of exposure (min)	*A. niger*	*A. fumigates*	*G. apiculatum*	*V. elodea*
0	100	100	100	100
15	9.60 ± 0.73^{a}	13.79 ± 4.04^{b}	19.41 ± 0.41^{c}	51.59 ± 1.15^{d}
30	15.37 ± 0.15^{a}	22.68 ± 4.35^{b}	22.85 ± 0.33^{b}	58.35 ± 1.39^{c}
45	38.81 ± 0.54^{b}	8.83± 1.88^{a}	39.81 ± 0.38^{b}	71.71 ± 1.47^{c}
60	46.22 ± 1.55^{a}	47.49± 4.62^{a,b}	51.52 ± 0.09^{b}	80.16 ± 0.69^{c}

Values are mean ± standard deviation (SD) of replicates (n = 3). Values with the same alphabet in a row are not significant at P = 0.05.

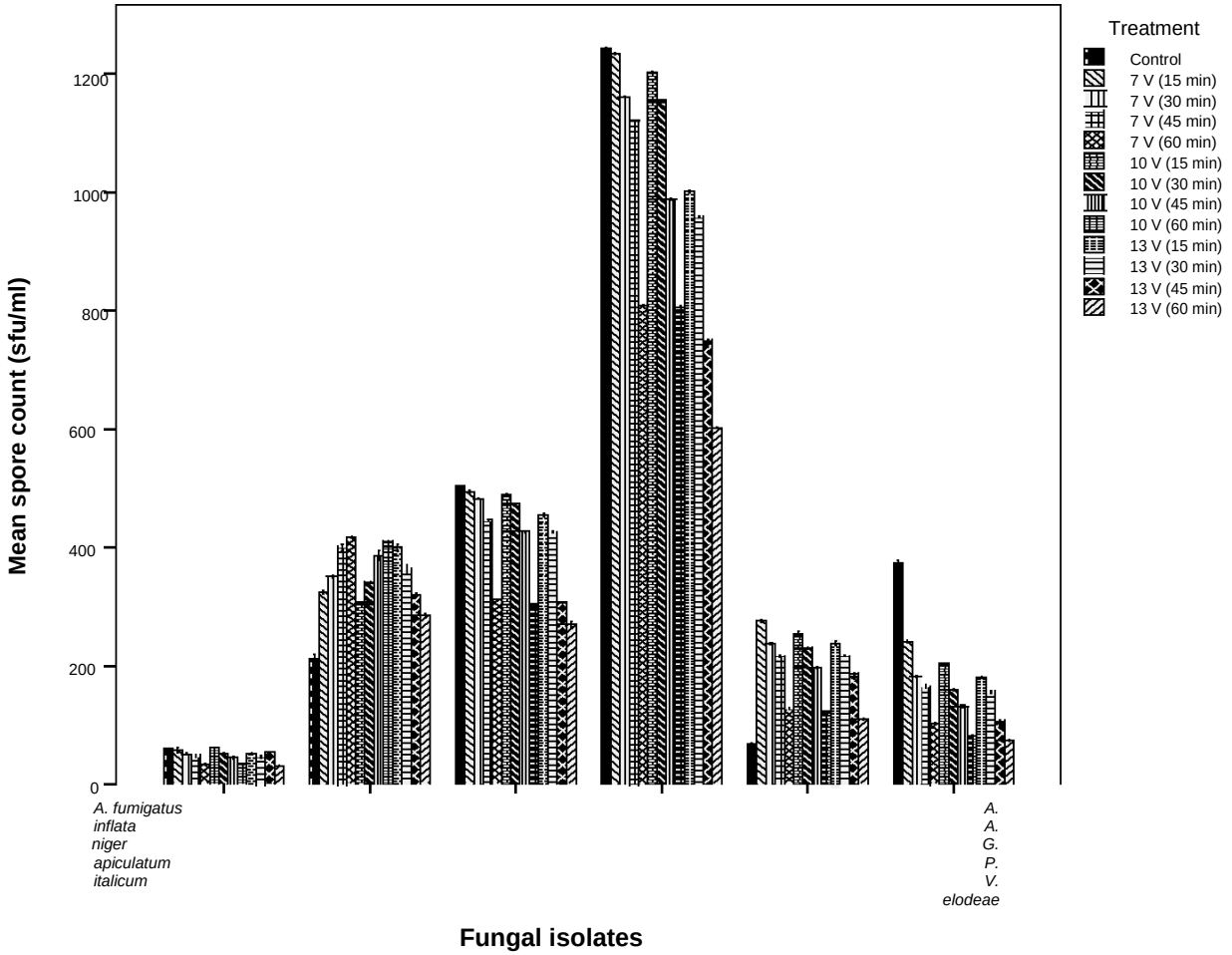

Figure 1. Reaction of spores of fungal isolates from pawpaw to electromagnetic field.

was recorded as compared to the control. The result of the proximate and mineral analysis of the fruits showed that there is no significant difference between most of the nutrient component of the treated and untreated fruits (Table 5). This shows that the electromagnetic field has no side effects on the nutrient components of the fruits. Simpson et al. (1995) reported that there were no physical or chemical changes in ascorbic acid and sugars in PEF-treated apple juice and that a sensory panel found no significant difference between untreated and electric field-treated juices.

The occurrence of fungal spoilage of fruits has been recognized as a source of potential health hazard to man and animals. However, growing interest in what is commonly known as healthy and safe food, that is, food with a high nutritive value can be observed world-wide. The findings of this research work revealed that electromagnetic field wave has the potential to drastically reduce post-harvest spoilage fungi which has been of major concern to farmers and food industries. Therefore, electromagnetic field wave can be used as a means of controlling these spoilage fungi, thereby increasing the

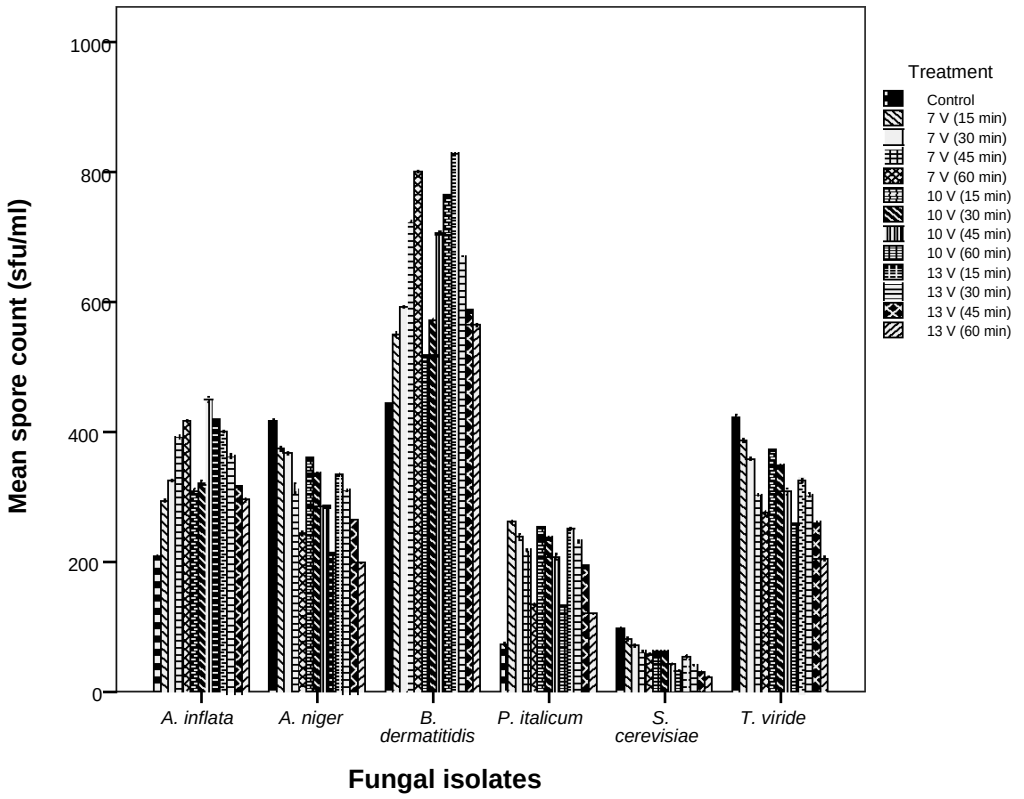

Figure 2. Reaction of spores of fungal isolates from sweet orange to electromagnetic field.

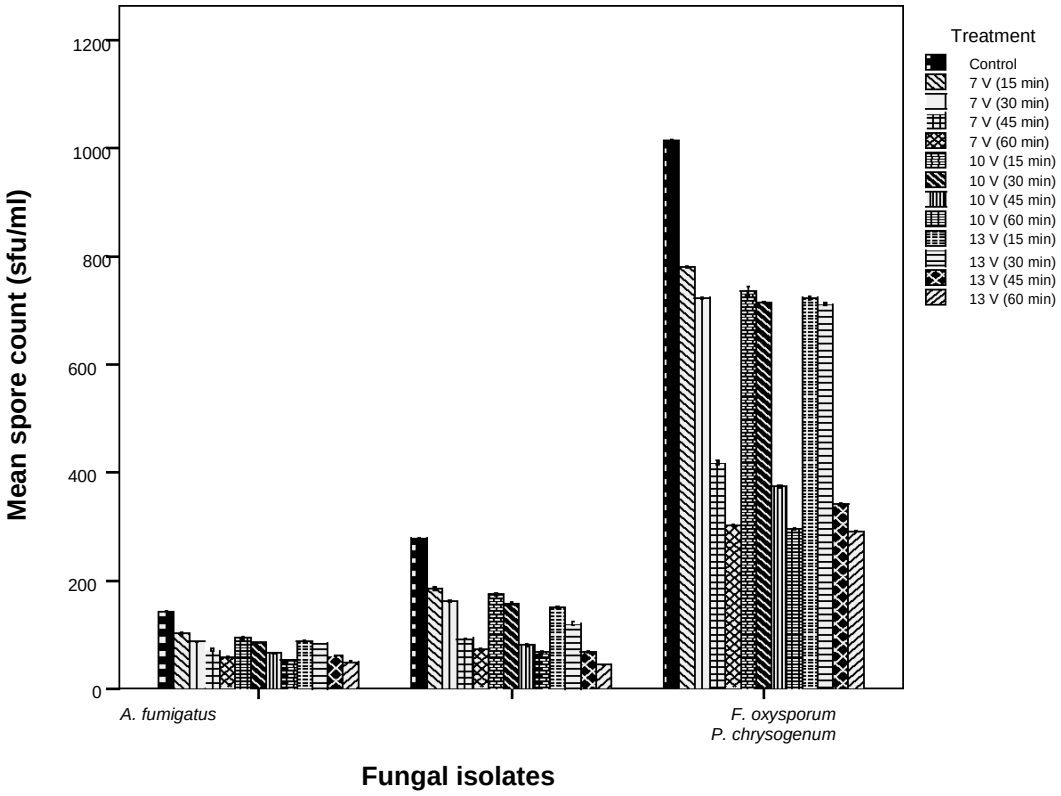

Figure 3. Reaction of spores of fungal isolates from banana to electromagnetic field.

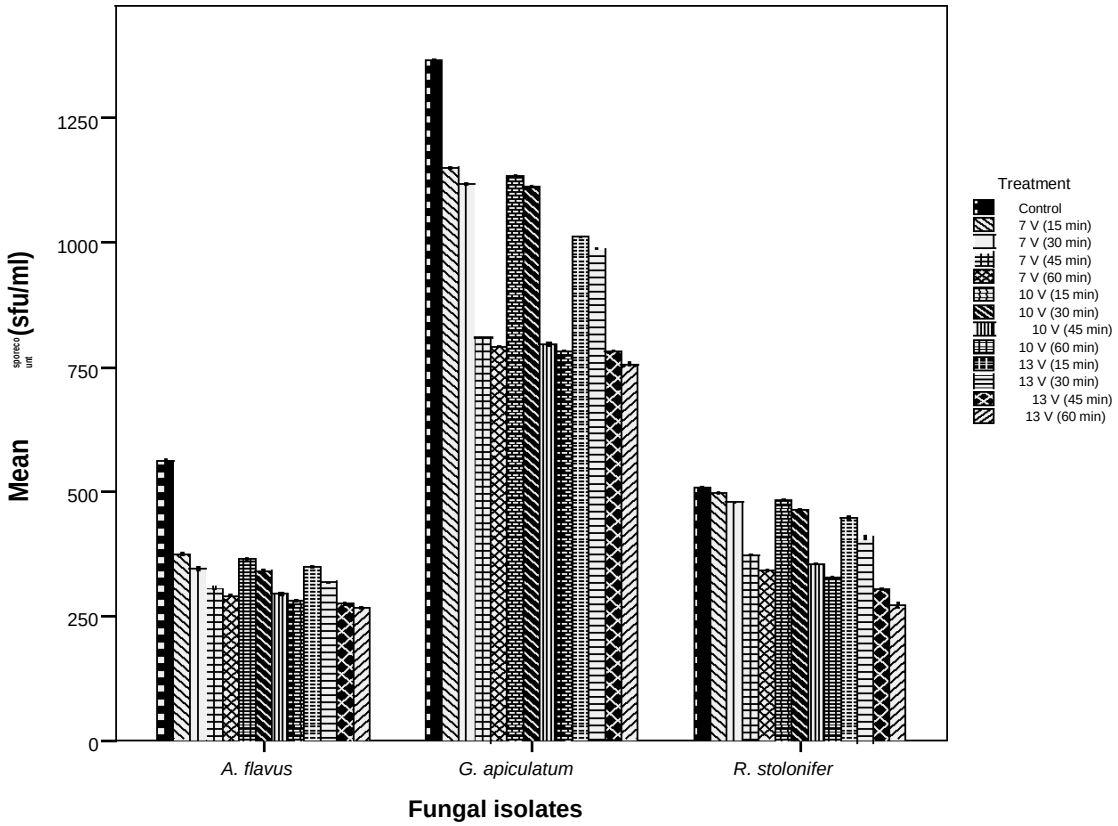

Figure 4. Reaction of spores of fungal isolates from garden egg to electromagnetic field.

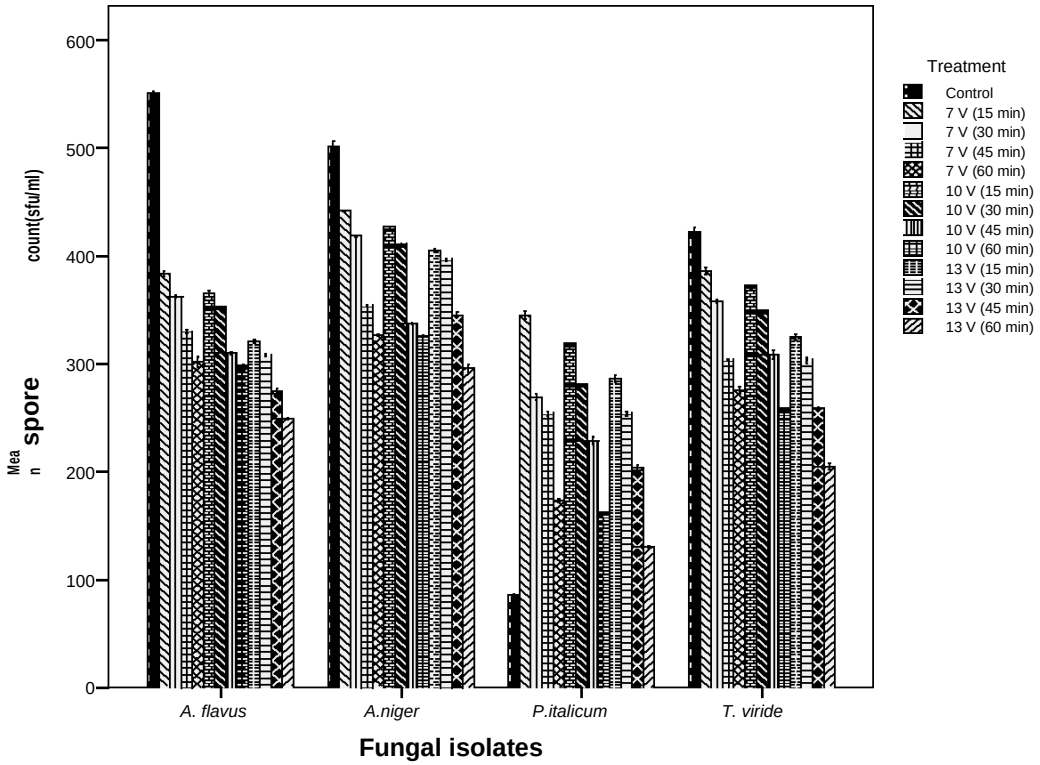

Figure 5. Reaction of spores of fungal isolates from lemon to electromagnetic field.

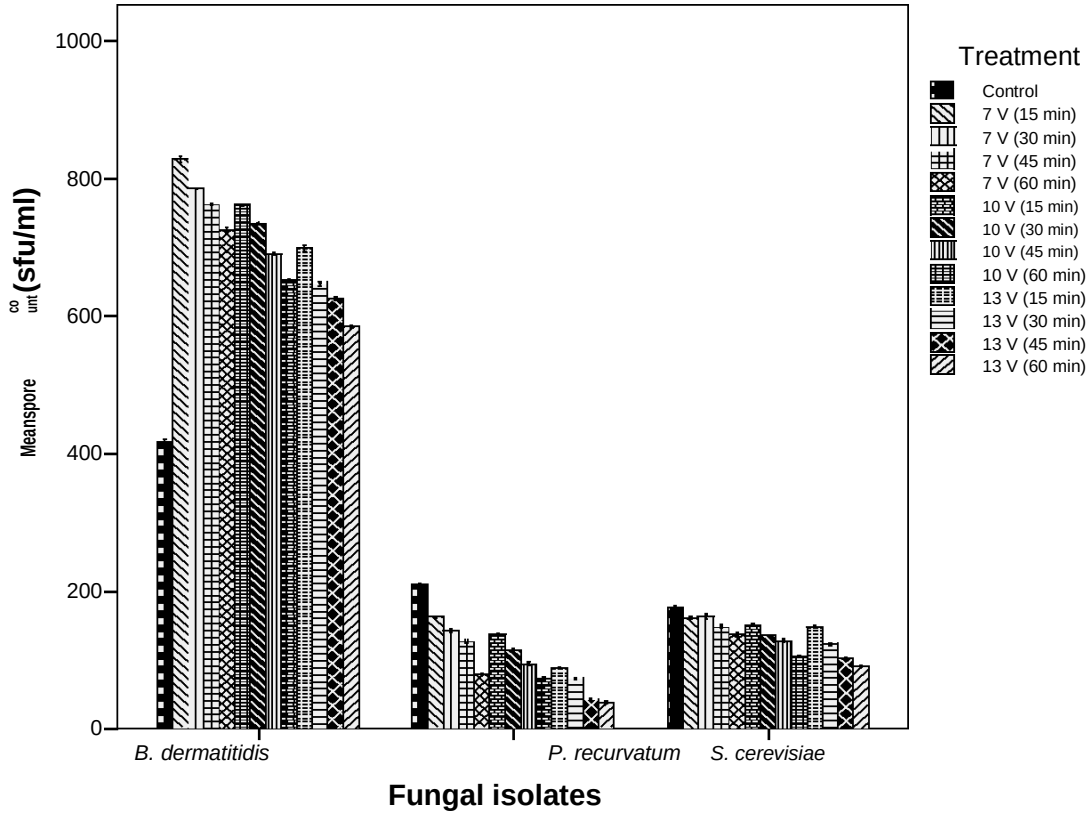

Figure 6. Reaction of spores fungal isolates from tangelo to electromagnetic field.

Table 5. Proximate and mineral composition of untreated and treated selected berry.

Fruit	Moisture (%)	Dietary fibre (g)	Fat (g)	Protein (g)	Ash (g)	Carbohydrate (g)	Mg (mg)	Ca (mg)	K (mg)	Vitamin C (mg)
Untreated fruit										
Pawpaw	81.60 ± 0.20	1.69 ± 0.01	0.15 ± 0.01	0.64 ± 0.04	0.54 ± 0.02	9.23 ± 0.36	8.73 ± 0.31	22.00 ± 2.00	252.67 ± 2.31	59.60 ± 1.44
Sweet Orange	80.20 ± 0.20	2.53 ± 0.31	0.22 ±0.01	0.71 ± 0.01	0.58 ± 0.02	10.90 ± 0.06	9.60 ± 0.40	39.33 ± 1.16	160.67 ± 3.06	43.33 ± 1.53
Banana	61.20 ± 0.20	2.47 ± 0.31	0.30 ± 0.01	1.10 ± 0.02	0.75 ± 0.01	22.89 ± 0.01	25.53 ± 0.50	4.93 ± 0.12	348.67 ± 1.16	8.13 ± 0.23
Garden Egg	66.80 ± 0.20	1.87 ± 0.12	0.45 ± 0.01	0.18 ± 0.01	0.30 ± 0.01	11.2 ± 0.20	14.00 ± 0.00	8.62 ± 0.54	232.00 ± 2.00	2.19 ±0.01
Lemon	84.07 ± 0.11	2.4 ± 0.40	0.29 ± 0.02	1.09 ± 0.01	0.56 ± 0.01	9.32 ± 0.13	8.40 ± 0.40	24.63 ± 0.04	134.33 ± 4.04	50.00 ± 2.00
Tangelo	74.00 ± 4.00	1.97 ± 0.08	0.09 ± 0.01	0.63 ± 0.01	0.44 ± 0.04	8.40 ± 0.70	9.00 ± 0.31	35.00 ± 0.40	140.00 ± 2.00	40.33 ± 1.16

Treated fruit										
Pawpaw	80.67 ± 0.15	1.67 ± 0.03	0.15 ± 0.00	0.63 ± 0.01	0.55 ± 0.01	8.87 ± 0.42	8.31 ± 0.27	21.00 ± 1.00	250.78 ± 3.24	56.96 ± 2.60
Sweet Orange	78.67 ± 1.16	2.4 ± 0.20	0.20 ± 0.04	0.71 ± 0.01	0.60 ± 0.01	10.50 ± 0.46	9.06 ± 0.31	38.00 ± 0.00	160.00 ± 2.00	41.33 ± 1.16
Banana	59.67 ± 1.53	2.47 ± 0.30	0.30 ± 0.02	1.07 ± 0.03	0.75 ± 0.01	22.00 ± 1.00	24.49 ± 0.63	4.48 ± 0.43	345.40 ± 1.22	7.93 ± 0.12
Garden Egg	65.33 ± 1.16	1.8 ± 0.20	0.44 ± 0.04	0.18 ± 0.02	0.29 ± 0.01	11.07 ± 1.10	12.87 ± 1.02	7.86 ± 0.24	230.00 ± 0.00	2.16 ±0.04
Lemon	82.67 ± 2.31	2.33 ± 0.31	0.29 ± 0.01	1.07 ± 0.03	0.58 ± 0.01	9.20 ± 0.17	8.13 ± 0.23	24.06 ± 0.12	135.33 ± 1.16	47.33 ± 1.15
Tangelo	77.33 ± 3.06	1.96 ± 0.69	0.08 ± 0.00	0.633 ± 0.03	0.44 ± 0.04	8.42 ± 0.69	8.06 ± 0.30	32.00 ± 0.00	162.00 ± 1.88	40.33 ± 1.12

Values are mean ± Standard Deviation (SD) of replicates (n = 3).

shelf life of fruits, respectively; though, extra care should be taken during personal handling of these fruits; such as harvesting, cleaning, sorting, packaging, transport, and storage to prevent high level of contamination. Further investigation should however be carried out to ascertain the consequences of consuming electromagnetic-treated fruits by man.

REFERENCES

Akinmusire OO (2011). Fungal species associated with the spoilage of some edible fruits in Maiduguri northern eastern Nigeria. Adv. Environ. Biol. *5*(1):157-161.

AOAC (Association of Official Analytical Chemist) (2006). Official methods of analysis (18th ed.). Washington.

Bali RV, Bindu MG, Chenga RV, Reddy K (2008). Post harvest fungal spoilage in sweet orange (*Citrus sinensis*) and acid lime (*Citrus aurentifolia* Swingla) at different stages of marketing. Agric. Sci. Digest 28:265-267.

Barnett HL, Hunter BB (1998). Illustrated genera of imperfect fungi, 4th ed. American Phytopathology Society, USA. ISBN 978-0-89054-192-0.

Chuku EC, Ogbonna DN, Onuegbu BA, Adeleke MTV (2008). Comparative studies on the fungi and biochemical characteristics of Snake Gaurd (*Trichosanthes curcumerina* linn) and Tomato (*Lycopersicon esculentus* mill) in Rivers State, Nigeria. J. Appl. Sci. 8(1):168-172.

Effiuvwevwere BJO (2000). Microbial spoilage agents of tropical and assorted fruits and vegetables (An Illustrated References Book). Paragraphics Publishing Company, Port Harcourt. pp. 1-39.

Gaskova D, Sigler K, Janderova B, Plasek J (1996). Effect of high-voltage electric pulses on yeast cells: Factors influencing the killing efficiency. J. Bioelectrochem. Bioenerg. 39:195-202.

Jarupan K, Mohammad NE (2008). Application of non-thermal processing for preservation of orange juice. Kmitl Sci. Technol. J. 8(2):64-74.

Mizuno A, Hori Y (1991). Destruction of living cells by pulsed high-voltage application. IEEE Trans. Ind. Appl. 24(3):387-394.

Monso EM (2004). Occupational asthma in greenhouse workers. Curr. Opin. Pulm. Med. 10:147-150.

Moulder JE (2002). The electric and magnetic fields research and public information dissemination (EMF-RAPID) Program. Radiat. Res. 153:613-616.

Nijis DV, Egmond HP, Rombouts FM, Notermans SHW (1997). Identification of hazardous *Fusarium* secondary metabolites occurring in food raw materials. J. Food Safety 17:161-191.

Olutiola PO, Famurewa O, Sonntag HG (2000). An introductory to general microbiology. A practical approach. Bolabay Publication, Lagos Nigeria. pp. 124.

Onuegbu BA (2002). Fundamentals of crop protection, ASCEU, RSUST, Port Harcourt, pp. 204-208.

Petzinger E, Weidenbach A (2002). Mycotoxins in the food chain: The role of ochratoxins. Livest. Prod. Sci. 76:245-250.

Pol IE, Mastwijk HC, Bartels PV, Smid JE (2000). Pulsed-electric field treatment enhances the bacterial action of nisin against *Bacillus cereus*. Appl. Environ. Microbiol. 66:428-430.

Qin BL, Chang FJ, Barbosa-Cánovas GV, Swanson BG (1995). Nonthermal inactivation of *S. cerevisiae* in apple juice using pulsed electric fields. Lebensm Wiss Technol. 28(6):564-568

Qin BL, Zhang Q, Barbosa-Cánovas GV, Swanson BG, Pedrow PD (1994). Inactivation of microorganisms by pulsed electric fields with different voltage waveforms. IEEE Trans. Dielectr. Insul. 1(6):1047-1057.

Rashad RA, Ahmed RA, Saleh AM (2011). Isolation and identification of some fruit spoilage fungi: Screening of plant cell wall degrading enzymes. Afr. J. Microbiol. Res. 5(4):443-448.

Roha KK, Mohammad RS (2005). Effect of static electric field treatment on multiple antibiotic-resistant pathogenic strains of *Escherichia coli* and *Staphylococcus aureus*. J. Microbiol. Immunol. Infect. 38:394-398

Simpson MV, Barbosa-Cánovas GV, Swanson BG (1995). The combined inhibitory effect of lysozyme and high voltage pulsed-electric field on the growth of *Bacillus subtilis* spores. IFT Annual Meeting: Book of Abstracts. pp. 267.

Strasak L, Vetterl V, Smarda J (2002). Effects of low-frequency magnetic fields on bacteria *Eschericia coli*. Bioelectrochemistry 55:161-164.

Tournas VH, Stack ME (2001). Production of alternariol and alternariol methyl ether by *Alternaria alternata* grown on fruits at various temperatures. J. Food Prot. 64:528-532.