Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 7, No. 5, p. 150-156, 2015
http://www.innspub.net

INNSPUB
RESEARCH PAPER
OPEN ACCESS

The effect of non-thermal plasma to control of stored product pests and changes in some characters of wheat materials

Shahrzad Mohammadi[1], SohrabImani[1*], Davoud Dorranian[2], Siavash Tirgari[1], Mahmoud Shojaee[1]

[1]*Department of Entomology, Science and Research Branch, Islamic Azad University, Tehran, Iran*
[2]*Plasma Physics Research Center, Science and Research Branch, Islamic Azad University, Tehran, Iran*

Article published on November 30, 2015

Key words: Non-thermal Plasma, Stored product pests, wheat characters, Dielectric-barrier discharge.

Abstract

Pesticides greatly reduce the damages caused by pests but they entail some risks. The point of the study was to examine the effect of non-thermal plasma (NTP) on *Tribolium confusum* (Coleoptera, Tenebrionidae) and *Ephestiakuehniella*(Lepidoptera, Pyralidae) and possible changes in somecharacters of treated wheat. For each pest, Three hundred and sixty 2-3 instar larvae among wheat at 5 separate groups were used.Fat, protein, ash and moisture content of wheat were measured. Experiments were done by a completely randomized designin triplicates. The results indicated that NTP has sufficient insecticidal effect.Mean percentage of mortality reached to 100%±0 after 20 s for both pests. A positive correlation was observed between exposure time and mean percentage of mortality.Non-significant difference was found between the treated and untreated groups in case of wheat traits.It is concluded that application of NTP can be considered as an appropriate alternative.

***Corresponding Author:** Shahrzad Mohammadi ✉ imanisohrab@gmail.com

Introduction

*Tribolium confusum (*Coleoptera, Tenebrionidae) and *Ephestiakuehniella* (Lepidoptera, Pyralidae) feed on various stored products such as flour and cereals (Shafique *et al*., 2006). *T. confusum* is attracted to grains containing high moisture and drastically reduce the quality and quantity of the infected products (Ahmed and Ahmed,2002). The beetles emit unpleasant odor and can expedite the growth of the fungus in the contaminated products (Rustamani, 2014).*E.kuehniella*populations will increase rapidly if there is suitable condition for larval development. Silky webs produced by the larvae in density leads to increased humidity and the formation of moulds, which can produce toxins.

Application of fumigants is one of the main strategies to control of stored product pests (Pinniger and Harmon,1999).Methyl bromide was successful fumigant in controlling of insect pest in post-harvest for a long time (Schneider *et al.,* 2003). But after recognizing the destructive effect of methyl bromide on the ozone layer, its consumption was prohibited (EPA,2004), and trying to find suitable replacements has been started. Methyl bromide alternatives due to some limitations including high cost, impact on the commodity, difficulty of performance and resistance to them have not been developed yet (Lebedev *et al*., 2013, Kevin *et al*., 2006, Visalakshy and Krishnamoorthy, 2012).

A favored substitute might be the application of Non-thermal Plasma (NTP) (Bures *et al.,* 2006).NTP frequently was used for industrial purposes such as air filtration (Kelly-Wintenberg *et al.,* 2000), treatment of hazardous waste (Eliasson and Kogelschatz, 1991) and microbial decontamination (Efremove *et al*., 2000,Laroussi *et al*., 2003,Montie *et al*., 2000, Moreira *et al*., 2004)and promising results have been obtained. NTP is formed at atmospheric pressure, thus its application on thermally sensitive products is possible. There is likely that surface modification can be done without changes on properties(Kevin *et al*., 2006).

Following the successful results of NTP in microbial decontamination (Efremove *et al*., 2000, Montie *et al.,* 2000).Mishenko *et al*., (2000) applied a combination of radiation and plasma at entomology branchagainst *Sitophilusgranaries,* for the first time. Keever *et al*., (2001) affected *Lasiodermaserricorne* by NTP and counted mortality of the adults .

Donohue *et al*., (2006) tested the effect of plasma (HTA-250A power) on *Frankliniellaoccidentalis*, *F. fusca*, *Aedesalbopictus, Tetranychusurticae* and *Blatellagermanica* for 60, 90,120 and 180 s. Indianmeal Moth*, Plodiainterpunctella*larvae and pupae were exposed to atmospheric pressure plasma jet (APPJ). The number of APPJ pulses and distance from nozzle of APPJ were variable. Mortality, malformation and the emergence of offspring were observed.(Abd El-Aziz *et al*., 2014). Bures *et al*., (2006) recorded the mortality of *Myzuspersicae, Planococcuscitri and Pediculushumanu s*treated by NTP after 1, 3, 5 and 24 h.

Given that NTP was applied in various fields and promising results have been obtained (Birmingham and Hammerstorm, 2000, Mizuno, 2007) it can be considered as aneco-friendly alternativefor chemical methods.but limited studies have been done on the use of NTP for pest control in warehouse.To suggest application of NTP, more studies on its insecticidal effect and impacts ontreated commodities should be tested.So the study was done for assessing the effect of NTP on *T. confusum* and *E.kuehniella*. The study was concerned with possible changes in some characters of wheat including Fat, protein, ash and moisture content between treated and control groups.

Material and method

Insect

T. confusum and *E.kuehniella* were collected from contaminated flour and transferred to Entomology laboratory .Adults were kept in plastic bottles and fed by wheat, wheat flour, yeast and bran. Adults were removed after 24 h and their offspring were reared in incubator at 26±2 ^{o}c and 65±5 r.h.

Dielectric Barrier Discharge (DBD) Device

APPD was generated between parallel electrodes by using the device in fig1. The discharge is taking place in normal atmospheric air, at frequency about 13 kHz. To generate DBD plasma a modified AC high voltage power supply was used. During all experiments, the applied voltage of the device was 10 kV. The room air was used and no separate gases were added.

Mortality assays

For each pest, Three hundred and sixty 2-3 instar larvae at separate five groups were used for bioassay tests. In any test, insects among wheat were placed between two electrodes and exposed to NTP for various times (2, 5, 10, 20 and 30 sec). The experiment was carried out in triplicates. For every stage, one group with sufficient replicates was left untreated as control.

Biochemical tests

To measure fat, ash and moisture contents AACC 30-25.01, AACC 08-01.01 and 44-16A respectively was used. Calculation of protein values were carried out according to the AOAC (1980).

Statistical analysis

Experiments were done by a completely randomized design. Obtained results were analyzed by the help of SPSS program ver.18. Independent T-test was used to determine the differences between the mortality of*T. confusum* and *E. kuehniella* and the treated and untreated groups in terms of wheat traits groups. Results were reported as Mean ± SEM. The level of significance for each experiment was set at $P < 0.05$ .excel software used for Drawing curves and estimating of R square and equation of regression line.

Results

Effect of plasma on insect mortality

The insects were exposed by plasma forvarious times and the mean percent mortalityoftreated bio tests are shown in table1.It is apparent from this table that the maximum mortality (100±0) for *T. confusum* was found in 20 s and the minimum(38.88±1.66) observed in the treatment 2 s. Mean percentage mortality for *E.kuehniella* reached to 100% at20 s treatment and 2 s resulted in the lowest mortality(28.57±0.57). Data for *T. confusum* can be compared with *E. kuehniella* which shows similarity. Mortality was increased, with gaining the time.Slopes of the regression line were 20.26 and 21.12 for *T. confusum* and *E. kuehniella* respectively (table.1) that confirmed a positive correlation between exposure time and mortality. It is noteworthy that, Mortality for 45, 60 and 75 s was 100 % that the results are not mentioned in the table. NTP had sufficient insecticidal effects on the both bio tests andstatistical tests revealed no significant differences between mortality of *T. confusum* and *E. kuehniella* (p=.89).

Table 1. Mean percent mortality of *T. confusum* and *E. kuehniella* larvae exposed to non-thermal Plasma for various time periods.

Pest	Exposure time(S)	Mean mortality (%)	Slop of regression line	R square
T. confusum	0	0±0	20.26	88%
	2	38.88±1.66		
	5	66.66±1.1		
	10	92.7±1.92		
	20	100±0		
	30	100±0		
	0	0±0	21.12	91%
E. kuehniella	2	28.57±0.57		
	5	62.50±1.15		
	10	87.50±0.88		
	20	100±0		
	30	100±0		

Lethal time values

Table 2 illustrates lethal exposure times at the 50, 90% level for the bio tests. As can be seen from the table (below), LT50 are 2.83 and 3.53(s) for *T. confusum* and *E. kuehniella* respectively. Slopes of the probit curvesare estimated 2.64 and 2.78 for *T. confusum* and *E. kuehniella*.

Effect of plasma on wheat characters

Some factors of treated and untreated wheat including Fat, protein, ash and moisture contents were listed in table3.Measured fat for control and treatment was 1.12±0.01 and 1.14 ±0.02respectively. Protein values were calculated 7.85±0.02 for control and 7.85±0.01 for treatment. Ash content of control (1.50±0.02) and treatment (1.50±0.14) was the same.Moisture content was recorded 5.80±0.28 and5.63±0.35 for treated and untreated wheat.

Table 2. Lethal exposure times at the 50, 90% level for *T. confusum* and *E. kuehniella*.

Pest	LT50(s)	LT90(s)	Slope	Chi-square	df	*P* value
T. confusum	2.83 (1.77-3.82)	8.63 (6.22-15.54)	2.64	5.32	3	.15
E. kuehniella	3.53 (3.04-4.02)	10.20 (8.70-12.50)	2.78	4.47	3	.21

Discussion

Various insects cause quantitative and qualitative lossesin stored products per year. Chemicalpesticides widely are used to control stored product pests(Konradsen *et al.,* 2003).With respect to thenegative effect of pesticides on the environment,trying to find suitable alternatives,is the subject of many studies. (Coronado *et al.*, 2004).Ozone or essential oil introduced as replacements, but due to high cost, negative environmental effects and other weaknesses have not developed yet (Bures, 2004, Bures *et al.*, 2006).NTPwas applied in various biological researches like sterilization and chemical decontamination and hopeful findings were recorded (Laroussi, 2002, Montie *et al.*, 2000). Lethaleffect of NTP on pestshas been tested in limited studies.

Table 3. Mean values of fat, protein, ash and moisture contents of the tested wheat.

Factor	Control (%)	Treatment (%)	t	df	pv	Significant difference
Fat	1.12±0.01	1.14±0.02	-0.80	7	.46	-
Protein	7.85±0.02	7.85±0.01	0.45	7	.67	-
Ash	1.50±0.02	1.50±0.14	-.019	7	.98	-
moisture	5.80±0.28	5.63±0.35	0.55	7	.61	-

Obtained results proved insecticidal effect of NTP against *T. confusum* and *E. kuehniella*.In both cases, Mortality reached to 100% after 20 s.Statistical test showed that there is no significant difference between mortality of *T. confusum* and *E.* kuehniella(p=.89). At first study on insecticidal effect of NTP 100% mortality was counted(Mishenko *et al.*, 2000) which proved the results of the present study.Ninety-two percent of mortality was reported in exposed *Lasiodermaserricorne* with NTP. The resultssimilar to our findings confirmed that NTP can control various pests successfully.(Keever *et al.*, 2001).

By changing some variables such as time, can change the insecticidal effect of plasma. In accordance with Donohue *et al.*, (2006) our results showed a positive correlation between exposure time and mortality for both pests.Our results confirmed by Abd El-Aziz *et al.*, (2014), who found that NTP has effect on*Plodia interpunctella*survival. Larval and pupal mortality

was gained with increasing of APPJ pulses and decreasedby reduction of distance from the jet.

Mode of actionplasma on various living tissues like bacteria, mammalian cells and insects has been studied,but significantly different mechanisms were proposed (Dobrynin *et al.*, 2009).In the case of gram-positive bacteria, damage to the cell membrane has been introduced as the cause of death(Mendis*et al.*, 2002). While, Donohue *et al.*, (2006) observed some behavioral changes in treated cockroaches and they recommended that NTP affect nervous and neuromuscular system.Abd El-Aziz *et al.,* (2014) said that Larvae are more susceptibility compared with pupa that can be due to sclerotized cuticle of pupa. Different mechanisms can be related to different methods of plasmagenerationand differences in the structure of organisms.

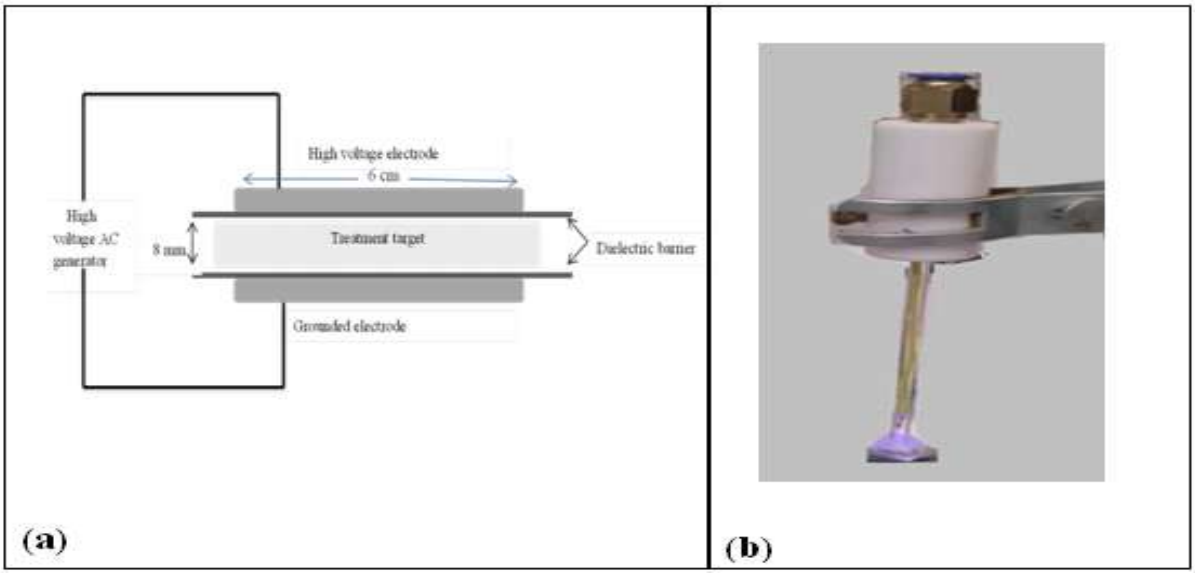

Fig. 1. A schematic of the DBD Device (a) and a schematic of the plasma jet Device (b).

NTP has a couple of advantages. It can be generated at ambient temperature with low electrical power and has no harmful effect on appearance of the treated products.In the study, non-significant changes were observed between treated and untreated wheat in point of measured characters .This accords with Rehn and Viol (2003) observations, which found no considerable changes in *Hordeum vulgare* seeds exposed to plasma.

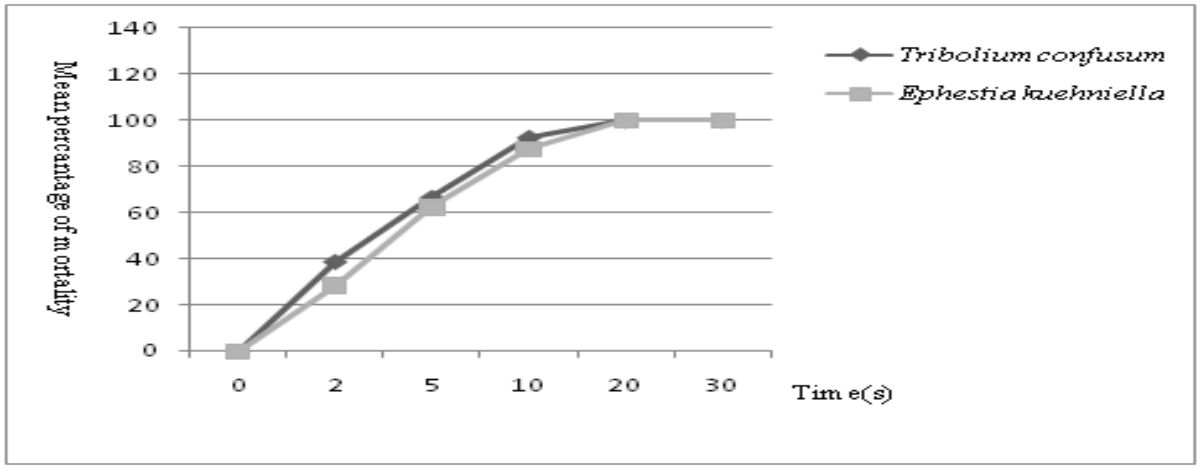

Fig. 2. Comparison of mortality rate for *T. confusum* and *E. kuehniella* larvae.

Not only the negative effect of plasma on the product has not been reported,Dobinov *et al.,* (2000),stated thatgermination rate of *Avena sativa* seeds was increased after treating by plasma.

In a nutshell, the possibility of using NTP for pest control is considerable.Short time of treatment, flexibility and lack of harmful residues are the advantages of this method which can be noted.Physics exports are hopeful to use of NTP for cereal and other stored products during transport to the silos.Although, further studies are required to use a new technology and various aspects of its application must be examined.The mechanism of plasma and histological changes at treated insects can be part of future studies, as well.

Acknowledgment

The authors would like to thank Mr.Ostadi and Mrs. Hoseini for their technical assistance and Mr.Nikmaram and Mrs. Amini for their helpful comments.

References

AACC. 2000. "Approved methods of American Association of Cereal Chemists".

Ahmad M, Ahmad A. 2002. Storage of food grains.Farming outlook **1,** 16-20.

AOAC. 1980. Official Methods of Analysis. Washington, DC: Association of Official Analytical Chemists.

Birmingham JG, Hammerstrom DJ. 2000. Bacterial decontamination using ambient pressure nonthermal discharges. IEEE Transactions on Plasma Science **28,** 51-55.

Bures BL, Donohue KV, Roe RM, Bourham MA. 2006. Nonchemical dielectric barrier discharge treatment as a method of insect control.IEEE Transactions on Plasma Science **34,** 55-62.

Coronado GD, Thompson B, Strong L, Griffith WC, Islas I. 2004. Agricultural task and exposure to organophosphate pesticides among farmworkers. Environmental Health Perspectives **112,** 142–147 .

Dobrynin D, Fridman G, Friedman G, Fridman A. 2 0 09.Physical and biological mechanisms of direct plasma interaction with living tissue. New Journal of Physics **11,** 115020.

Donohue KV, Bures BL, Bourham MA, Roe RM. 2006. Mode of action of a novel nonchemical method of insect control: atmospheric pressure plasma discharge. Economic entomology **99,** 38-47.

Efremov NM, Adamiak BY, Blouchin VI, Dadashev SJ, Dmitriev KI, Gryaznova OP, Jusbashev VF. 2000.Action of a self-sustained glow discharge in atmospheric pressure air on biological objects.IEEE Transactions on Plasma Science **28,** 238-241.

Eliasson B, Kogelschatz U. 1991. Non-equilibrium volume plasma chemical processing. IEEE Transactions on Plasma Science **19,** 1063-1077.

Environmental Protection Agency [EPA]. 2004. Protection of stratospheric ozone: process for exempting critical uses from the phaseout of methyl bromide; final rule. Federal Register **69,** 76982-77009.

Keever D, Dowdy AK, Bures BL, Hankins OE, Bourham MA. 2001. Mortality and sterility of the cigarette beetle, *Lasiodermaserricorne*(F.), due to exposure to atmospheric plasma. ,Annual Research Conference on Methyl Bromide Alternatives and Emissions Reductions **128,** 1 -4.

Kelly-Wintenberg K, Sherman DM,Gadri RB, Karakaya F, Chen Z, Roth JR, Montie TC. 2000. Air filter sterilization using a one atmosphere uniform glow discharge plasma. IEEE Transactions on Plasma Science **28,** 64-71.

Konradsen F, Van der Hoek W, Cole DC, Hutchinson G, Daisley H, Singh S, Eddleston M. 2003. Reducing acute poisoning in developing countries-options for restricting the availability of pesticides.Toxicology **192,** 249-261.

Laroussi M, Alexeff I, Kang WL. 2000. Biological decontamination by non -thermal plasmas.IEEE Transactions on Plasma Science **28,** 184-188.

Laroussi M. 2002. Nonthermal decontamination of biological media by atmospheric-pressure plasmas: review, analysis, and prospects. IEEE Transactions on Plasma Science **30**, 1409-1415.

Lebedev G, Abo-Moch F, Gafni G, Ben-Yakir D,Ghanim M. 2013. High-level of resistance to spinosad, emamectin benzoate and carbosulfan in populations of Thripstabaci collected in Israel. Pest Management Science **69,** 274-277.

Mishenko AA, Malinin OA, RashkovanVM, Basteev AV, Bazyma LA, Mazalov YP, Kutovoy VA. 20 0 0 .Complex high-frequency technology for protection of grain against pests. Microw. Power Electromagn. Energy **35,** 17 9 -18 4.

Mizuno A. 2007. Industrial applications of atmospheric non-thermal plasma in environmental remediation. Plasma Physics and Controlled Fusion **49,** 1-15.

Montie TC, Kelly-Winterberg K, Roth JR. 2000. An overview of research using the one atmosphere uniform glow discharge plasma for sterilization of surfaces and materials. IEEE Transactions on Plasma Science **28**, 41-50.

Moreira AJ, Mansano RD, Pinto TJA, Ruas R, Zambon LS, Silva MV, Verdonck PB. 2004. Sterilization by oxygen plasma. Applied Surface Science **235,** 151-155.

Rustamani MA, KhatriI, Sultana R, laghari MH. 2014. Population Fluctuation of Red Flour Beetle, *Tribolium castaneum* (Herbst.) (Coleoptera: Tenebrionidae) on Different Cereal Foods in Laboratory.Pakistan Journal of Zoology **46,** 1511-1514.

Schneider SM, Rosskopf EN, Leesch JG, Chellemi DO, Bull CT, Mazzola M. 2003. United States Department of Agriculture – Agricultural Research Service research on alternatives to methyl bromide: pre-plant and post-harvest. Pest Management Science **59,** 814-826.

Shafique M, Ahmed M, Chaudry MA. 2006. Feeding preference and development of *Tribolium castaneum* (Herbst.) in wheat products.Pakistan Journal of Zoology **38,** 27-31.

Visalakshy P, Krishnamoorthy A. 2012. Comparative field efficacy of various entomopathogenic fungi against *Thripstabaci*: prospects for organic production of onion in India. Acta Horticulturae **33,** 433-437.

Weston PA, Rattlingourd PL. 2000. Progeny production by *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Oryzaephilussurinamensis* (Coleoptera: Silvanidae) on maize previously infested by *Sitotrogacerealla* (Lepidoptera: Gelechiidae). Economic Entomology **93,** 533-536.