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FINAL REPORT

PROJECT NO.US-3276-01

**Disinfestation of Mediterranean and Mexican Fruit
Flies in Citrus Using Radio and Microwave Energy**

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Project Title: Disinfestation of Mediterranean and Mexican Fruit Flies in Citrus Using Radio and Microwave Energy

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Abbreviations commonly used in the report, in alphabetical order:

ARO	Agricultural Research Organization
ARS	Agricultural Research Service
BARD	Binational Agricultural Research and Development
CMBI	Citrus Marketing Board of Israel
DP	dielectric properties
EC	electrical conductivity
HBS	heat block system
MeBr	methyl bromide
Medfly	Mediterranean fruit fly
RF	radio frequency
TDT	thermal-death-time
USA	United States of America
USDA	United States Department of Agriculture
WSU	Washington State University

Budget: IS: \$175,000

US: \$175,000

Total: \$350,000



Signature

Principal Investigator

Signature

Authorizing Official, Principal Institution

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Abstract

Original objectives; revisions during the course of project

The original objectives of the project were: 1) to determine the kinetics of thermal mortality of different developmental stages of fruit flies to different treatment conditions; 2) to study the responses of citrus fruit to electromagnetic radiation to control fruit flies; 3) to investigate the mode of action of response of both organisms (flies and fruit) to electromagnetic radiation; and 4) to select the optimal conditions for treatment and conduct tests to validate efficacy of treatment protocols. We received a non-cost extension of the project for two years and revised the original objectives during the extended period, in which the efficacy tests were switched from Israel to Hilo, Hawaii, USA because of the high cost of purchasing and transporting a RF unit from the industrial supplier (Strayfield, UK) to Israel. This final task was not completed because the shipped RF unit could not be allocated in the USDA-ARS Pacific Basin Research Center in Hilo due to special electricity supply requirements.

Background to the topic

USA and Israel collectively account for approximately 53 and 16% of the world production of grapefruits (*Citrus paradisi* Macfad.) and oranges (*Citrus sinensis* L. Osbeck). About 67% of citrus produced in the world is marketed as fresh, with major citrus-producing countries also acting as major fresh fruit exporters. The Mediterranean, *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), and Mexican fruit fly, *Anastrepha ludens* (Loew) (Diptera: Tephritidae), are among the world's most pervasive and economically damaging insect pests in citrus. Wild outbreaks of those pests are responsible for millions of dollars in damages each year in Israel and the USA, in spite of ongoing quarantine procedures. Commercially viable commodity treatments are a critical component of quarantine and pest management strategies, because these treatments provide the sole means of maintaining commercial markets for fresh fruits in the event of a wild fruit fly outbreak and imposed quarantine. Existing commodity treatments for citrus, such as cold storage, methyl bromide (MeBr) fumigation or forced hot air, are lengthy and expensive, or they adversely affect fruit quality and/or the environment. Radio frequency (RF) energy used commercially in food industry and potentially in disinfesting walnuts could be applied to improve the conventional heating for disinfesting fresh produce of fruit flies.

Major conclusions, solutions, achievements

The heating block system (HBS) provided a fast and uniform heating tool for thermo-tolerance studies and possible comparisons of thermo-tolerance among different life stages and species of targeted insects. The experimental thermal mortality data for the two fruit flies and the corresponding death kinetic model serve as a fundamental basis for developing practical thermal treatment protocols. We improved heating uniformity in RF assisted water heating of oranges by using a newly designed fruit mover resulted in acceptable orange quality in postharvest insect control treatments.

Scientific and agricultural implications

The project addressed highly sensitive and urgent issues related to technical trade barriers and environmental concerns because of the on-going phasing-out of MeBr fumigation mandated by international treaties. The thermal death kinetic data of the two fruit flies obtained in this project are important information needed in developing thermal treatments. The research methods and strategies developed in this study can be used in the development of other environmentally-friendly insect pest control processes based on thermal energy. The availability of non-chemical thermal treatment alternatives will enhance both environment and human health by reducing the use of agrochemicals. Our research serves as a good starting point for the development of effective, rapid, and environmentally friendly insect pest control processes based on RF energy.

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Achievements

Significance of main scientific achievements or innovations

We have developed a heating block system (HBS) at WSU and installed it both at USDA-ARS, Weslaco, TX and CMBI in Israel for this project. The development and adoption of a uniform HBS is a major step to quantify thermal mortality for targeted insect species. Using the same HBS, we have determined thermal death kinetics of different life stages of Medfly and Mexican fruit fly from 46 to 52°C. The thermal-death-time (TDT) curves showed that the third-instars were more heat resistant than eggs of Medfly, especially at the two low temperatures (46 and 48°C). The Medfly was found to be more heat tolerant than the Mexican fruit fly. Quarantine heat treatments for commodities that could be infested by both species, such as fruit in Mexico and parts of Central America, need only be researched with Mediterranean fruit fly, as any heat treatment to control it would control Mexican fruit fly.

We determined dielectric properties (DP) of citrus and fruit flies as a function of temperatures. The dielectric loss factor of citrus and flies decreased with increasing frequency at constant temperatures and increased almost linearly with increasing temperature at 27 MHz RF frequency. The small difference of the loss factor between citrus and flies would not result in differential heating when subjected to RF systems. The DP data were useful in improving RF heating uniformity by matching the electrical conductivity (EC) of the medium with that of fruit and helping to determine the optimal design parameters in simulation.

We have developed a fruit mover at WSU to improve RF heating uniformity in oranges. The results showed that, with rotation and movement of fruit, temperature uniformity in oranges was significantly improved with less than 2.8°C standard deviations after an average temperature rise of about 30°C in 7.8 min. The RF assisted hot water heating improved further the heating uniformity among and within oranges after preheating in a water bath. RF heating to 48°C and holding for 15 min in hot water would meet the quarantine security without impairing the quality of the treated oranges. The quality parameters included: weight loss, loss in firmness, color change, total soluble solids, and acidity. This fruit mover is an effective tool to develop a treatment protocol for disinfesting fresh fruit and to simulate industrial scale and continuous treatment systems.

We developed a simulation model using commercial finite element method-based FEMLAB software to predict the heating pattern in various geometries in a parallel plate RF system. The RF heating energy did not increase linearly with increasing the dielectric loss factor of an object but reached a broad maximum depending on the geometric shape of the objects, surrounding medium and air gap above the objects. On the other hand, the relative horizontal and vertical position of the fruit with respect to electrodes significantly influenced the heating pattern inside of the fruit. The simulation study corroborated that movement and rotation of the fruit was the only plausible solution for improving heating uniformity of spherical fruits. The developed modeling tool could predict the heating pattern of individual fruit as influenced by dielectric properties, size, shape, and surrounding media in designing thermal treatments for specific commodities.

Agricultural and economic impacts

A critical component of citrus industry is the phytosanitation and quarantine treatments to control insect pests in citrus. Improved methods of disinfestation would expedite the export of domestic citrus products. A successful treatment of disinfestation would retain the existing market and develop new markets. One such method, RF technology, showed much promise in eliminating the two fruit flies in oranges with acceptable product quality. The systematic, multi-disciplinary approach and fundamental methodology established in the research and the field tests will benefit other researchers working on the development and implementation of alternative thermal

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treatments for postharvest insect control as well as increasing the efficiency and speed with which we develop effective protocols.

Details of cooperation

The Medfly is endemic in Israel and cannot be researched in the mainland USA where it is not endemic and could become established. Commodity quarantine treatment research has historically been limited by these types of restrictions because each geographically isolated investigator has utilized a unique research approach or facility that is often not available to another researcher working with a similar pest or commodity. This binational research provided a unique cooperation opportunity to conduct complementary research on the Medfly in Israel and Mexican fruit flies in USA utilizing identical methodology. This project helped to conduct a series of experiments in leading research facilities in two countries involved in quarantine research and to develop treatment protocols for postharvest pest control in citrus. The following summarizes the details of the cooperation:

-Dr. Yoav Gazit visited WSU in Pullman, WA on May 21-24, 2002 and learned the installation and operation of the HBS. He also brought samples of frozen Medfly larvae for dielectric properties studies and discussed the research plan to complete the proposed objectives. In addition, he gained direct hands-on experience of heating fruit in the pilot-scale RF systems. In parallel, Dr. Shaojin Wang brought the similar HBS to USDA-ARS, Weslaco, TX on June 03-07, 2003 to demonstrate the installation and handling of the HBS. After that, both Israel and USDA-ARS laboratories conducted similar tests using the same equipment and method and determined the thermal death kinetics of the two fruit flies.

-Dr. Susan Lurie visited WSU, Pullman, WA on October 13-20, 2002 and October 21-26, 2003. She worked together with WSU partners to conduct preliminary evaluation on the heating uniformity of oranges in air and water when subjected to RF systems and taught an engineering graduate student to determine the heating effect on product quality, including weight loss, firmness, color and flavor. With Dr. Lurie's help, a standard procedure for product quality evaluation was established at WSU.

-BARD project provided a great opportunity for the scientists both in USA and Israel to work together on a book entitled "Heat Treatments for Postharvest Pest Control: Theory and Practice". In this book, three of the four editors were from this project and 7 book chapters were partially related to this project. This book will be published by CABI (UK) in 2008.

List of publications

- Hallman G., Wang S., Tang J., 2005. Reaction orders of thermal mortality of third-instar Mexican fruit fly *Anastrepha ludens* (Loew) (Diptera: Tephritidae). *Journal of Economic Entomology*, 98(6): 1905-1910.
- Wang S., Monzon M., Gazit Y., Tang J., Mitcham E.J., Armstrong J.W., 2005. Temperature dependent dielectric properties of selected subtropical and tropical fruits and associated insect pests. *Transactions of the ASAE*, 48(5): 1873-1881.
- Birla S.L., Wang S., Tang J., Fellman J., Mattinson D., and Lurie S., 2005. Quality of oranges as influenced by potential radio frequency heat treatments against Mediterranean fruit flies. *Postharvest Biology and Technology*, 38(1): 66-79.
- Gazit Y., Rossler Y., Wang S., Tang J., and Lurie S., 2004. Thermal death kinetics of egg and third-instar Mediterranean fruit fly *Ceratitidis capitata* (Wiedemann) (Diptera: Tephritidae). *Journal of Economic Entomology*, 97(5): 1540-1546.

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- Birla S.L., Wang S., Tang J., and Hallman G., 2004. Improving heating uniformity of fresh fruits in radio frequency treatments for pest control. *Postharvest Biology and Technology*, 33(2): 205-217.
- Wang S., Tang J., Johnson J.A., Mitcham E., Hansen J.D., Hallman G., Drake S.R., and Wang Y., 2003. Dielectric properties of fruits and insect pests as related to radio frequency and microwave treatments. *Biosystems Engineering*, 85(2): 201-212.

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Appendix

Publication Summary (numbers)

	Joint IS/US authorship	US Authors only	Israeli Authors only	Total
Refereed (published, in press, accepted) BARD support acknowledged	3	3	0	6
Submitted, in review, in preparation	0	0	0	0
Invited review papers	0	0	0	0
Book chapters	2	4	1	7
Books	1	0	0	1
Master theses	0	1	0	1
Ph.D. theses	0	1	0	1
Abstracts	0	0	0	0
Not refereed (proceedings, reports, etc.)	2	9	0	11

Postdoctoral Training: List the names and social security/identity numbers of all postdocs who received more than 50% of their funding by the grant.

Xinming Yin, visiting professor from China.

Cooperation Summary (numbers)

	From US to Israel	From Israel to US	Together, elsewhere	Total
Short Visits & Meetings	1	2	2	5
Longer Visits (Sabbaticals)	0	0	0	0

Description Cooperation:

See the detailed cooperation in the final report

Patent Summary (numbers)

	Israeli inventor only	US inventor only	Joint IS/US inventors	Total
Submitted	0			0
Issued (allowed)	0			0
Licensed	0			0