DISINFECTION AND DISINFESTATION OF NUT AND GRAIN PRODUCTS WITH RADIOFREQUENCY POWER.

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The consumption of nuts and grains has increased worldwide as consumers have realized their nutritional and health benefits. However, several outbreaks of foodborne illness have implicated tree nut products (almonds, peanuts) as well as other low-moisture foods (i.e. grains) with *Salmonella sp. (i.e., typhymurium, enteritidis*) or *Escherichia coli* O157:H7 being the most likely causing agents. The outbreaks have taken place despite the fact that a new chemical fumigant (i.e. propylene oxide) has been introduced to disinfect (pasteurize) these products. Outbreaks involving *Salmonella* or *E. coli* have been attributed to the consumption of contaminated almonds, sesame seeds products, and peanut butter in addition to various other nut products. While earlier, these products were known as somewhat likely to host viable human pathogens, recent research have clearly established that many low-moisture commodities are appropriate hosts to initiate the chain of events leading to outbreaks, as the survival of *Salmonella* appears to be enhanced in dry foods while becoming more resistant to a number of standard disinfection practices. In addition to these adaptation effects, even when initially at low concentrations, *Salmonella* or *E. coli* or other pathogens may pose health risks as these food products are usually subjected to long storage periods (1-2 years) before distribution and consumption. Recently, for raw almonds destined for human consumption, the Almond Board of California instituted an action plan defining several optional processes to pasteurize almonds (Almond Board of California, 2007). The plan was prompted and responded to announce new government regulations.

Insects can also cause considerable damage to nuts and grains during storage, with weight and nutritional losses reducing yields and market values. Furthermore, quality deterioration of grains intended for seedling purposes may cause further losses in quality and viability (germination) thus affecting yields in crop production. Under the current storage (bulk) conditions and long times, the presence of even a few viable colonies of insect pests may result in the emergence of much larger populations as the storage conditions are favorable to propagation due to the abundant presence of nutrients. In nut products, pests with the most potential economic impact include codling moths (*Cydia pomonella* [L]), navel orangeworm (*Amelois transitella* [Walker]), and Indianmeal moth (*Plodia interpunctella* [Hübner]) (Mitcham et al., 2004). Similarly, in paddy rice, two major insects Angoumois grain moths (*Sitotroga cerealella* [Oliver]) and lesser grain borers (*Rhyzopertha dominica* [F.]) represent major threats as primary grain insects whose larvae feed entirely inside the kernel of the grain and eat from inside becoming more tolerant to fumigation as diffusion of gas into kernels is severely restricted. Therefore, infestation with primary insects are critically more damaging to stored grains than secondary insects that eat grains from outside and are more easily controlled with conventional fumigation or heat treatments.

Methyl bromide fumigation was for many decades the preferred treatment applied to many food commodities to meet quarantine and phytosanitary restrictions and requirements in global agriculture markets. Current alternative methods used to control insects in rice include the use of insecticides (e.g. Malathion), fumigants (e.g. phosphine, carbon dioxide) and temperature treatment (Anonymous, 2004). Malathion (American Cyanamid Co., USA) is one of the safest organophosphate insecticides. Nevertheless, the treated rice should not be sold for at least 7 days nor eaten within 60 days after the treatment to avoid potential toxic effects from residues left. Phosphine gas is very toxic to human therefore its application requires strict controls, even though there is no residue left to the treated rice. Conventional carbon dioxide fumigation of rice usually requires a lengthy treatment (i.e. days, or even weeks) therefore its cost is high. Conventional high temperature treatments of rice, such as hot air or hot water immersion, are usually less effective to internally hidden eggs or pupae inside grain kernels. As adequate lethal temperature for insect pests need to be applied, surface overheating and diminishing quality attributes usually occurs due to slow heat conduction from the outside to the inside of grain kernels. Overheating also leads to the deterioration of grain quality and viability. For these reasons, there is a need to develop better, less or non invasive alternatives to disinfect grains and to overcome safety concerns while reducing risks to consumers, workers and the environment.

Radiofrequency (RF) power is an electricity-based technique capable of rapid and uniform heating of grains and nuts at thermal levels effective to simultaneously inactivate human pathogens and arthropod pests but below threshold levels causing changes in sensory and nutritional properties. RF uses oscillating electric fields whose energy is absorbed selectively and rapidly by dielectric or conductive pest materials leading to their biological inactivation. Pests are heated rapidly (45 to 75^{o}C; 3-5 min) inducing lethal conditions that are well tolerated by low-moisture foods. At UC Davis, novel applications have been developed (Lagunas-Solar et al., 2006, 2008), patented (USP # 6,638,475) and licensed for worldwide commercial use (see www.rfbiocidics.com). In this work, complete inactivation of *Salmonella typhimurium* in fresh almonds and full control of all life cycles of Angoumois grain moths (*Sitotroga cerealella* [Oliver]) and lesser grain borers (*Rhyzopertha dominica* [F.]) in rough rice, were used to validate RF disinfection and disinfestation effects while keeping the product's market and quality attributes. Economics of the RF process is competitive with chemical-based methods and automated operation based upon modern, solid-state reliable electronics is also feasible. The results summarized in this work (see Table 1 for almond disinfection; and Figures 1 to 3, for disinfestation effects on rough rice) clearly justify RF power as an emerging decontamination technology and an effective alternative to chemical fumigation.

REFERENCES CITED

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Table 1. Efficacy of RF power (~ 14.9 MHz, 500 W) disinfection as a function of temperature of *Salmonella typhimurium* inoculated almond samples. Samples incubated for 72 h at 37°C.				
RF processing	**Almond samples (n = 6)**	**Initial (av.) Inoculums (cfu/mL)**	**Colonies Detected.**	**Log_{10} Reduction**
	Batch 1			
None	Control	2.2×10^9	All positive	None
90°C (+ 5 min)	RF Treated	2.2×10^6	All negative	~ 6
	RF Treated	2.2×10^7	All negative	~ 7
	Batch 2			
None	Control	2.2×10^9	All positive	None
80°C (+ 5 min)	RF Treated	2.2×10^6	All negative	~ 6
	RF Treated	2.2×10^7	All negative	~ 7
	Batch 3			
None	Control	2.2×10^9	All positive	None
70°C (+ 5 min)	RF Treated	2.2×10^6	All negative	~ 6
	RF Treated	2.2×10^7	All negative	~ 7

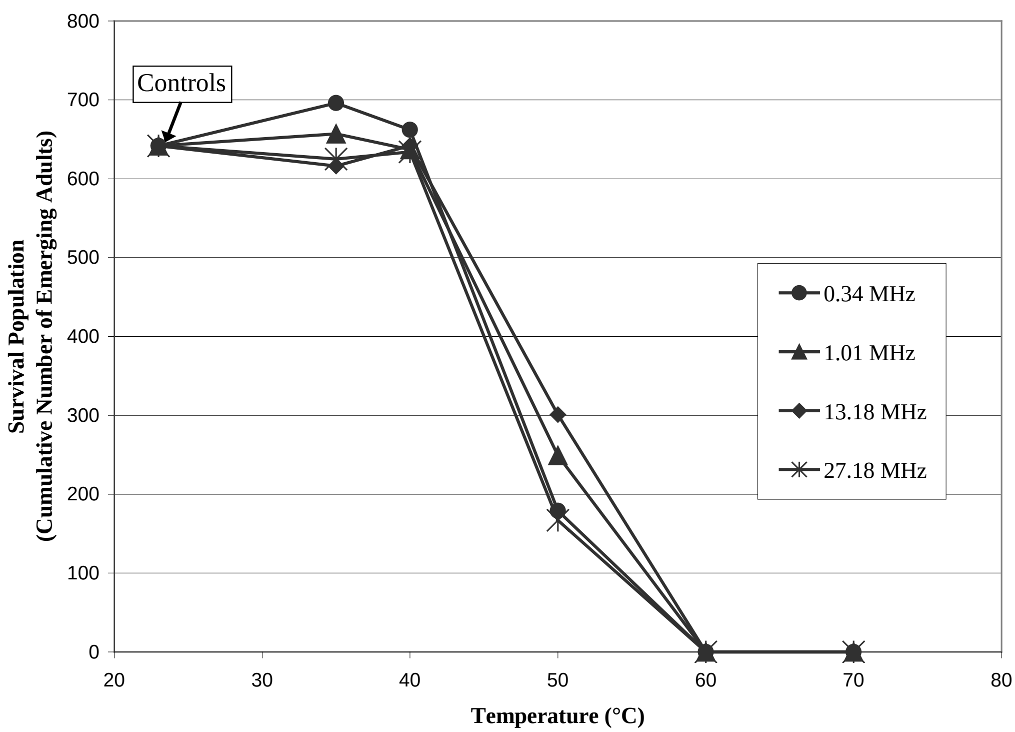

Figure 1. RF power disinfestation effects on *Sitotroga cerealella* at various RF frequencies and temperature.
Controls (not treated) in triplicate, RF treated samples in triplicate.

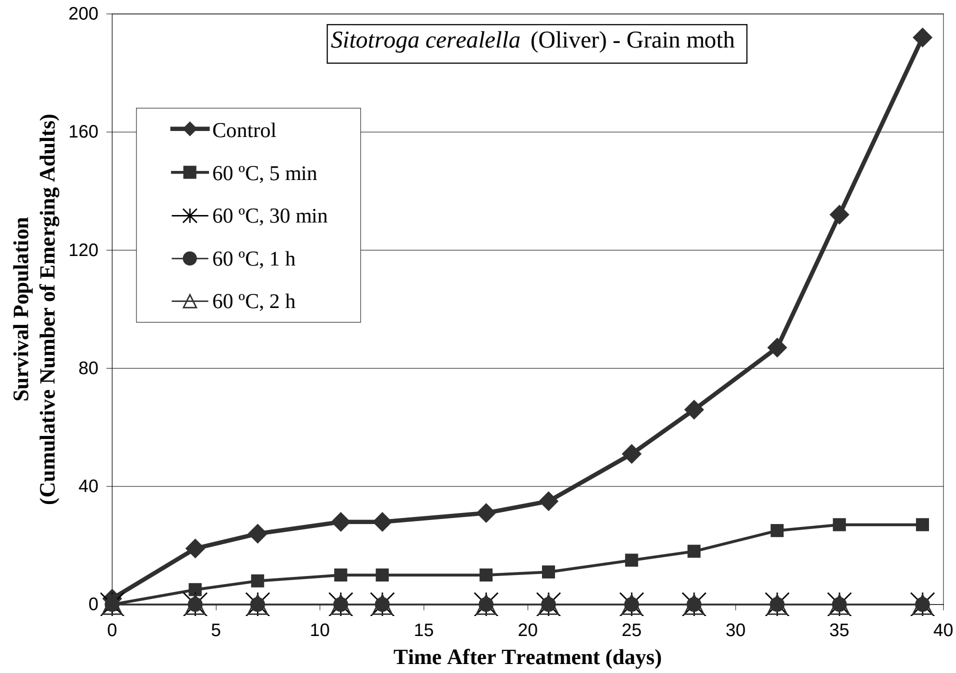

Figure 2. RF power disinfestation of *Sitotroga cerealella* grain moths in rough (paddy) rice with 20.3 MHz and 500W at different thermal load levels.
Controls (not treated) in triplicate, RF treated samples in triplicate.

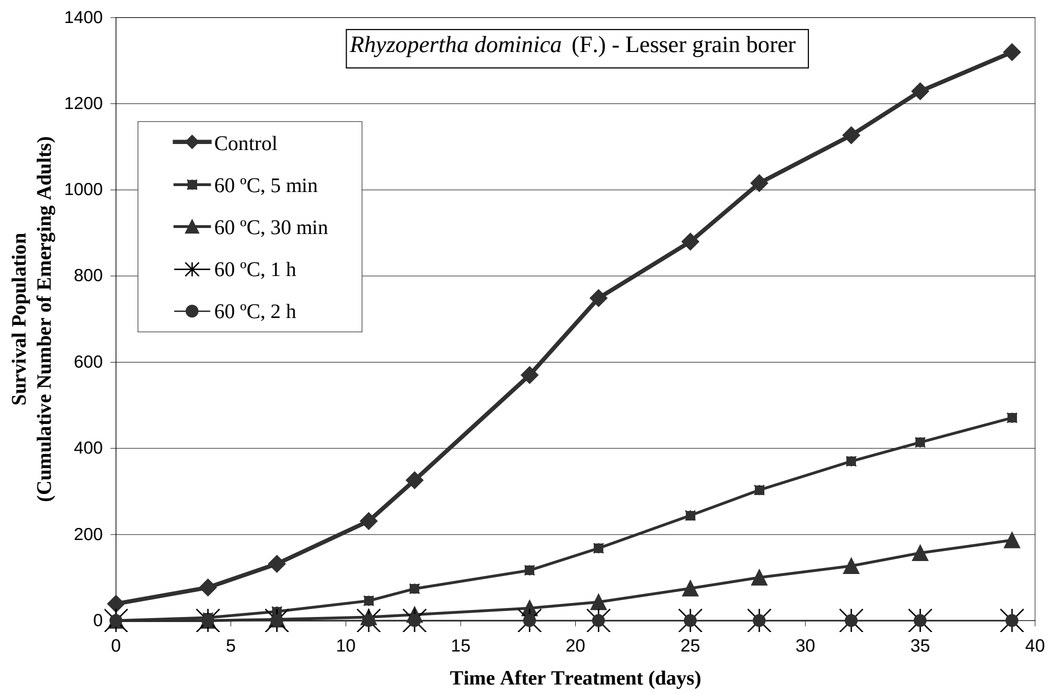

Figure 3. RF power disinfestation of *Rhyzopertha dominica* (lesser grain borers) in rough (paddy) rice with 20.3 MHz and 500 W at different thermal load levels.
Controls (not treated) in triplicate, RF treated samples in triplicate.