EVALUATION OF KAOLIN (SURROUND) FOR WALNUT HUSK FLY (*Rhagoletis completa*) CONTROL IN ENGLISH WALNUTS

W. W. Coates and R. A. Van Steenwyk

ABSTRACT

Three applications of kaolin (Surround) significantly reduced walnut husk fly damage from 98.0% to 1.2%. High label rates were applied to young 'Tulare' walnut trees by handgun. Field experience with air-blast sprayers has not been encouraging due to inadequate coverage. Excellent coverage and maintenance of residual from pre-oviposition to the end of the season appear to be essential. Sunburn was not reduced significantly in this trial by kaolin applications. Improved quality was noted in nuts harvested from treated trees, especially due to increases in nut size and decreased external shell damage. Value of the kaolin-treated nuts was 93.6 cents per pound versus 80.7 cents per pound for the untreated nuts. Nuts from the treated trees were harvestable more than a week before the untreated trees.

OBJECTIVES

Currently, there is no effective, organically acceptable control for walnut husk fly (*Rhagoletis completa*) in English walnuts. The purpose of this trial was to test the efficacy of a clay-based kaolin compound (trade name=Surround) for control of walnut husk fly (WHF). Surround is registered on walnuts as an organically acceptable pesticide. Surround has been shown to be efficacious for control of certain insect pests on other crops. The senior author presented preliminary evidence in *Walnut Research Reports – 2001* showing some efficacy against WHF.

PROCEDURES

The test orchard, south of Hollister, CA, consisted of young, 'Tulare' walnut trees spaced at 22'x22' (90 trees/acre). The 'Tulare' cultivar is considered very susceptible to WHF damage. The location of this orchard is in a district with a past history of early and severe WHF infestations.

A Trece Pherocon AM trap with an ammonium carbonate supercharger was placed in the orchard for monitoring purposes on May 15, 2002 and checked weekly through October 16. Traps were replaced and the supercharger refilled weekly.

The first spray application was applied on June 13 at a rate of 50 pounds Surround per 200 gallons of water per acre (2.22 gal/tree). A handgun sprayer operating at 200 psi was utilized. A total of ten trees were treated with a matching set of ten unsprayed trees as an untreated control. The second spray was applied July 10 at a rate of 75 pounds Surround per 150 gallons of water per acre (1.67 gal/tree). The higher rate of material combined with lower gallons of water per acre was utilized to reduce runoff and improve deposition on the leaves and nuts. A third spray was applied on August 15 at the same rate as the second spray. Excellent coverage of leaves and nuts was achieved following the second spray. The third spray was applied to replace nut residue worn off by wind rubs with leaves or removed by sprinklers on the lower portion of the tree.

RESULTS

The first WHF were caught in the trap on June 7. Trap counts remained at a low level until a rapid increase began on July 3 (table 1). At this time the first stings were observed. Trap counts remained high (up to 420 flies/per/trap/week) through the season until late September when counts began to drop (figure 1). When traps were removed at harvest on October 16 only a few flies were being caught.

The treated and untreated trees were rated for damage on October 8 with a visual inspection of 100 nuts per tree. Nuts were also rated for visible, severe sunburn (black, sunken areas). The results are shown below.

Treatment	% WHF Infested	%Visible Sunburn
Treated	1.2*	2.1
Untreated	98.0	4.4

*Significant at Fisher's L.S.D. 0.05

Samples of the treated and untreated nuts were submitted to Diamond Walnut for crackout quality analysis. The results for size and color are shown in table 2. The results for internal and external damage and value are shown in table 3.

DISCUSSION

The treated trees had significantly reduced WHF damage when compared to the untreated trees. Surround provides excellent protection from WHF damage if applied before damage occurs and if sufficient coverage is maintained throughout the season. Actual grower field experience suggests that it may be very difficult to get adequate coverage with an air-blast sprayer in mature trees. Our research applies only to young trees with application made by handgun at the highest labeled rate. Further testing should be pursued with air-blast equipment to determine whether adequate residues can be deposited on the nuts and whether one or two sprays can be utilized rather than three.

There was a numerical reduction in visible sunburn but it was not significant. Sunburn ratings only included visible, black sunken areas of severe sunburn. It is possible that more differences could have been documented by looking at hull surface browning or discoloration. Also, only three days of potentially harmful temperatures occurred during the time the nuts had kaolin residues – 100°F on 9/23 and 101°F on 8/9 and 9/1. More differences might have been noted in a season or district with more extreme maximum temperatures.

Quality can be improved with the application of Surround (tables 2 & 3). In past research, early WHF infestations have resulted in lower quality due to shrivel, mold and darker kernel color. In his trial, the most outstanding difference was in nut size. Treated nuts were significantly larger than the untreated nuts (98.2 % large versus 33.9% large). The treated nuts were also slightly lighter in kernel color but mold, insect damage, shrivel, and other internal damage were low in both treatments. Predictably, external damage (as shown by shell staining and adhering hull) was high in the untreated sample due almost exclusively to WHF, since incidence of both sunburn and blight were very low in this trial. The difference in overall calculated value (not actual 2002 crop value) was considerable – 93.6 cents/pound for the kaolin-treated sample versus 80.7 cents/pound for the untreated sample.

An interesting observation was that nuts from treated trees were harvestable more than a week before untreated trees. This unexpected occurrence may be due to earlier hull maturity or earlier whole nut maturity. If this occurrence can be repeated, it may lead to the use of Surround as an organic replacement for ethephon as a harvest aid. Further research needs to be done on this aspect of our results.

TABLE 1: Walnut Husk Fly Trap Catches -2002

Trece AM traps with ammonium carbonate superchargers

South of Hollister, CA, San Benito County, 'Tulare' cultivar

Date	Weekly Trap Catches	Flies Per Day
5/16/02	0	0.0
5/23/02	0	0.0
5/30/02	0	0.0
6/4/02	0	0.0
6/7/02	4	1.3
6/18/02	1	0.1
6/25/02	4	0.6
7/3/02	56	7.0
7/11/02	275	34.4
7/18/02	108	15.4
7/24/02	282	47.0
7/31/02	406	58.0
8/6/02	325	54.2
8/15/02	398	39.8
8/22/02	385	55.0
8/29/02	375	53.6
9/5/02	420	60.0
9/12/02	390	55.7
9/18/02	145	24.2
9/25/02	80	11.4
10/3/02	37	4.6
10/10/02	12	1.7
10/16/02	2	0.3

Trap placed in orchard 5/15/02

Trap replaced and ammonium carbonate added weekly

Commercial harvest 10/16/02

**TABLE 2: Walnut Husk Fly –Kaolin (Surround) versus Untreated, 2002
Quality Analysis-Size and Color, near Hollister, CA, San Benito County**

TREATMENT	SIZE %LARGE	KERNEL COLOR % X-LT	%LT	%LT-AMB	%AMB	RLI
Kaolin (Surround)	98.2	6.9	54.4	36.4	1.2	54.9
Untreated	33.9	8.6	43.2	42.1	2.8	54.6

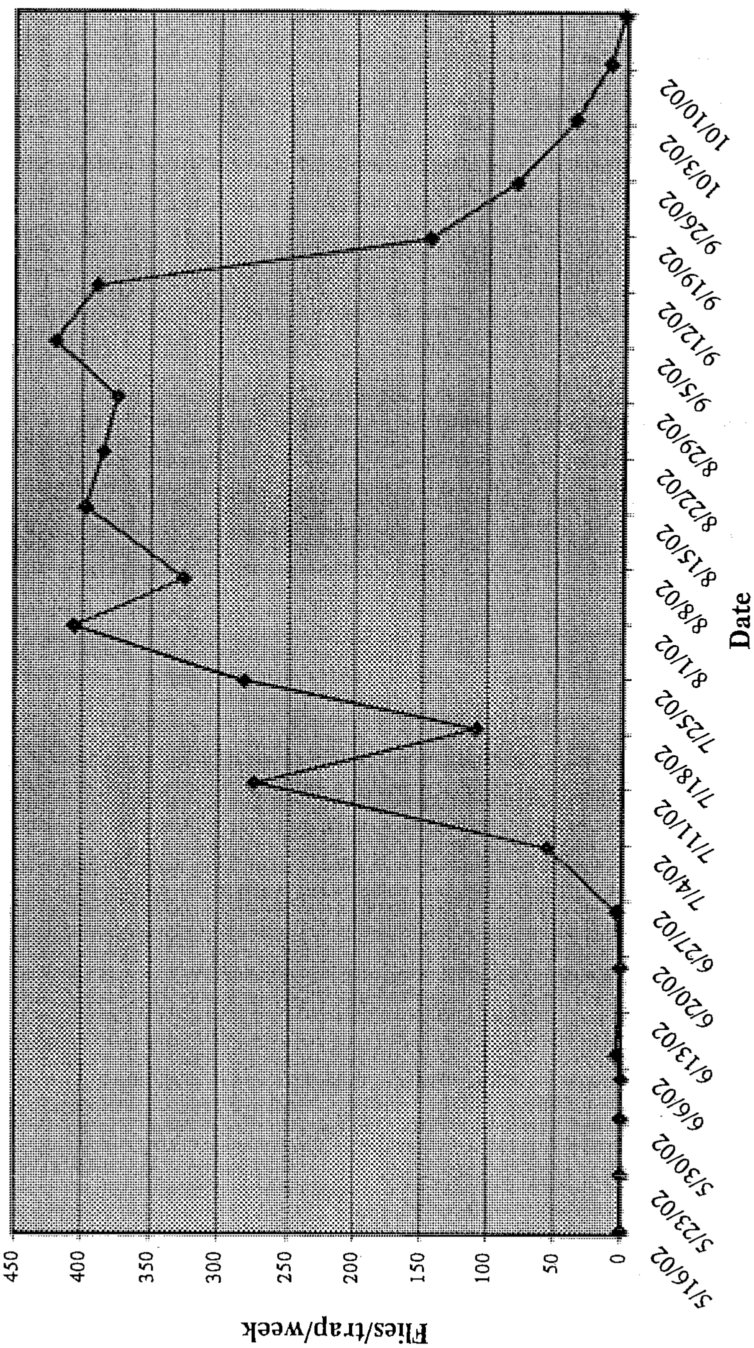
1000 g samples were harvested from each of 10 trees in each treatment.
Color ratings: X-LT = extra light, LT = light, LT-AMB = light amber, AMB = amber
RLI = relative light index, a measure of color (higher is better)

**TABLE 3: Walnut Husk Fly – Kaolin (Surround) versus Untreated, 2002
Internal and External Damage & Value, near Hollister, CA, San Benito Co.**

TREAT.	% INTERNAL DAMAGE MOLD	INSECT	SHRIV	OTHER	% EXTERNAL DAMAGE STAINED	ADH. HULL	VALUE CENTS/LB
Kaolin	1.0	0.0	0.6	0.0	0.1	0.9	93.6
Untreated	1.2	0.9	0.7	0.1	8.8	33.6	80.7

Mold = kernel surface mold, Insect = kernel damage (codling moth or navel orangeworm), Shriv = kernel shrivel, Other= other sources of kernel damage, Stained = stained shell (WHF damage), Adh. Hull = adhering hull (WHF damage), Value = calculated value in cents per pound of in-shell, dried walnuts (not calculated based upon actual 2002 crop value).

Figure 1: Walnut Husk Fly - 2002



APPLICATION OF RADIO FREQUENCY TREATMENTS TO CONTROL INSECTS IN WALNUTS

Elizabeth Mitcham, Rob Veltman, Xuqiao Feng, Bill Biasi, Tiffanie Simpson, Judy Johnson and Juming Tang and Shaojin Wang

ABSTRACT

Codling moth (*Cydia pomonella*), navel orangeworm (*Amyelois transitella*), and Indianmeal moth (*Plodia interpunctella*) are common insect pests in walnuts (*Juglans regia*). Currently, exported in-shell walnuts are disinfested using methyl bromide fumigation. Restrictions on methyl bromide use have increased interest in developing alternative postharvest treatments. Radio frequency heating is such an alternative.

Our tests have shown that heating walnuts with radio frequency energy to temperatures lethal to these important insect pests has no negative effect on walnut quality, and may even reduce the susceptibility for walnuts to become rancid in storage. We are in the process of confirming these results on a larger scale and optimizing the heating process for commercial use.

Standard factory settings of the radio frequency equipment of the Pomology Department (UCDavis) provided acceptable heating rates (less than 3 minutes to heat to lethal temperatures for insect pests) of the in-shell walnuts. Recently these settings were optimized for walnut, which shortened heating rates even more. The moisture content is an important factor affecting heating rates of walnuts during radio frequency heating. To investigate the heating rate over a broad range of moisture contents, nuts were submerged in demineralized water, and heating rates were determined after several drying periods. The relationship between the moisture content and the heating rate was shown to be linear, and the variability in moisture content was higher at a higher average moisture content.

Radio frequency treatment has been shown to decrease the moisture content of walnuts. Fumigation for insect control and drying of washed, in-shell walnuts are relatively time-consuming processes, and a combined system of radio frequency heating with hot air has the potential to accelerate or even replace batch drying of walnuts in the future. To be able to explore this potential of radio frequency energy, the experimental set-up of the Pomology Deparment was recently adapted with a hot air unit.

Previous work showed that of the most common insects that can be found in walnuts, the fifth instar navel orangeworm is the most heat tolerant. We have confirmed mortality of 200 fifth instar navel orangeworm larvae inserted into walnuts following heating of 500 in-shell walnuts to 131°F. Complete mortality occurred at temperatures between 127 and 131°F.

We will complete our work on walnut quality to determine the upper limit of tolerance to radio frequency heating. We plan to work with a walnut processor to test a commercial scale radio frequency unit, heating product on a conveyor running at commercial speeds. A demonstration of the radio frequency process is planned for February 2003 in Davis.

INTRODUCTION

Infestation by insect pests is a major problem encountered during the production, storage and marketing of walnuts (*Juglans regia* L.). The three most economically significant of these pests are codling moth (*Cydia pomonella*), navel orangeworm (*Amyelois transitella*), and Indianmeal moth (*Plodia interpunctella*). Larvae of codling moth and navel orangeworm are field pests and may be present in harvested walnuts. Codling moth is targeted by quarantine regulations in Japan and South Korea, and navel orangeworm is of phytosanitary concern in Australian and European markets. Indianmeal moth is a common pest of stored walnuts and is the insect most often responsible for consumer returns and complaints.

Methyl bromide (MeBr) fumigation is the usual treatment applied to in-shell walnuts to meet quarantine and phytosanitary requirements before shipment to domestic and international markets. Under the Montreal Protocol of the United Nations, MeBr will be banned from use for purposes other than pre-shipment and quarantine by 2005 (EPA, 2001). Greater regulation and restriction of MeBr use is likely to increase the cost of the fumigant, as well as reduce its availability. Sulfuryl fluoride may soon be registered for postharvest disinfestation of walnuts; however, there is interest in developing an alternative, non-chemical.

Alternative disinfestation treatments for walnuts include irradiation, cold storage, controlled atmospheres and heat treatments. Food irradiators are costly and there is concern over public acceptance of irradiated food. Cold storage and controlled atmosphere also require substantial capital investment and lengthy treatment times. This could make them unsuitable for the vital European holiday market, for which treatment times need to be less than 24 hours.

Conventional heating of walnuts is limited by the airspace around the kernel. This prevents efficient heat transfer between the inside and outside of the nut. However, radio frequency (RF) energy interacts directly with the moisture in the kernel, and so the inside and outside of the nut heat at similar rates. There is also evidence that insects heat preferentially, and so may reach higher temperatures faster than the surrounding nut. RF uses waves of magnetic and electric energy that interact as electromagnetic energy fields. RF radiation is low energy electromagnetic radiation in the frequency range of 30 Hz to 300 GHz. It is classified as "non-ionizing" radiation because these frequencies produce insufficient energy to ionize water molecules, unlike higher levels of energy such as x-rays and gamma rays that can alter molecular structures.

In developing a postharvest treatment for walnuts, tests must be done on the most tolerant life stage and species of the target insects. To determine this, treatments that result in 100% insect mortality need to be determined over a range of time-temperature combinations. Washington State University has developed a thermal block heating system to heat insects at various rates and to a range of different temperatures. Such experiments helped develop a "thermal death curve" for each species and life stage that was then tested using infested nuts in a radio frequency system.

Quarantine treatments need to result in Probit 9 insect mortality while also minimizing or avoiding damage to the product. It is therefore important to examine the effect on walnut quality of treatment times and temperatures that control the target pests. Quality factors for walnuts include crackability, kernel color, moisture content, rancidity and flavor. Walnut flavor and the development of rancidity can be indicated by peroxide values (PV, meq/kg) and fatty acids (FA, % oleic). Flavor is also measured by sensory evaluation using taste panels.

Understanding the factors that control the heating rate of walnuts with RF is critical to translate lab experiments to a commercial scale. Several of these factors required further attention, like the heating variability of the RF machine, the spatial orientation of the nuts during treatment, and most important the moisture content of batches of nuts and individual nuts.

OBJECTIVES

In our previous reports, we described the thermal death curve kinetics for fifth-instar codling moth and navel orangeworm larvae. We also conducted some initial tests using RF energy to control third-instar codling moth in in-shell walnuts. Core temperatures inside walnuts treated with RF increased to 127.4°F in 3 min. A 5 min holding time at this temperature resulted in 100% kill of insects without affecting either PV or FA content. Practical protocols were developed to control the targeted insects. RF heating to 131°F followed by 5 min of forced 131°F air resulted in 100% mortality of the fifth instar navel orangeworms. Rancidity, sensory qualities and shell characteristics were not negatively affected by the RF treatments. The process slightly reduced the moisture content of the walnut kernels.

The objectives of this next stage of the research were:

1. Study scaling-up small-scale treatment protocols to commercial processes.

2. Study the possibility of using RF to control insect pests and at the same time reducing non-uniform moisture content in washed in-shell walnuts.

3. Refine treatment protocols with infested walnuts to reduce treatment times and increase throughputs.

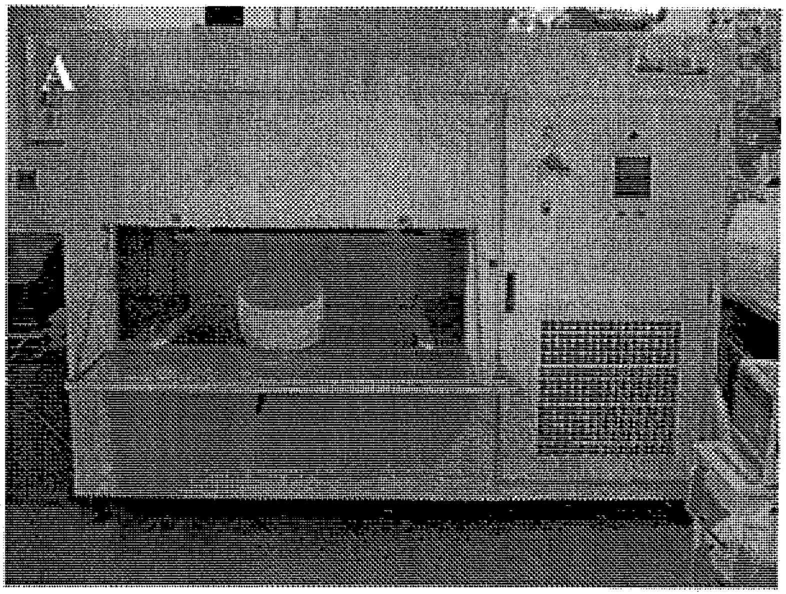
4. Determine effects on walnut quality following long term storage.

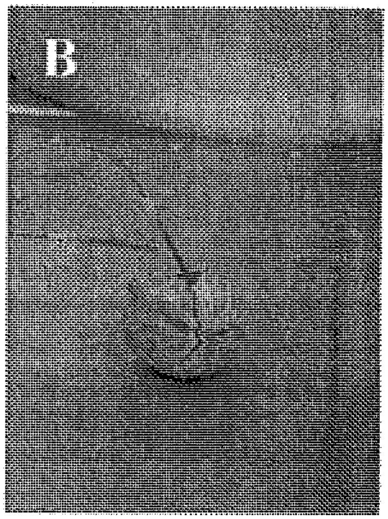
5. Sensory analysis of walnuts treated with refined protocol.

6. Laboratory demonstration at UCDavis for industry.

PROCEDURES

Initial tests





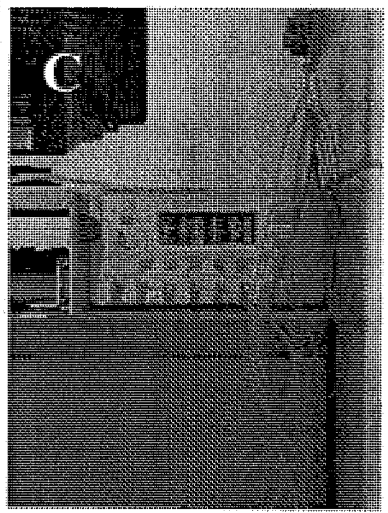


Figure 1.

A. RF machine and the experimental container: experimental set-up

B. Optical temperature sensor attached to a walnut kernel. A small hole was drilled into the kernel after the shell had been partly removed

C. Interface used for sensor read-out

The postharvest lab of the Pomology Department, UCDavis is equipped with a 27 MHz, 12 kW batch radio frequency machine (RF, Strayfield International Limited, Workingham UK, Fig. 1A). Before walnut disinfestation studies could be performed, some initial tests were needed. These initial tests were to map the uniformity of the RF field within the machine. Knowledge about the uniformity of the electromagnetic field in the RF unit is important to be able to determine the heating variability caused by the machine and the variability caused by the product. Two types of initial tests were done to investigate the heating uniformity of the RF machine.

1. By measuring the temperature of tap water in several glass jars, which were equally distributed over the lower electrode of the RF machine, the temperature distribution of the RF field was established.

2. It was investigated if mixing of the nuts during treatment decreased the heating variability. To do so, a simple mechanism was developed (two ropes attached to the sample container) to manually rotate the container. Nuts were heated with and without rotation in the RF, and heating rates and temperature variability of individual nuts were compared. In these experiments the standard nut heating protocol was used.

Nut Heating Protocols

Nuts were heated in a round, polyethylene container with a diameter of 13.2 inch and a height of 7.87 inch until the coldest of the 8 walnuts that were monitored reached the target temperature of 127.4°F, or to another temperature when indicated (Fig. 1B). The container was filled completely (about 500 nuts) in all experiments. During operation the standard settings of the RF were: 8.27 inch gap between the lower and upper electrode, a minimum gap of 8.07 inch, 12kW power, and a maximal treatment time of 10 minutes.

During heating the kernel temperature of the nuts was monitored using 8 fiber-optic probes (Nortech Fiberonic Inc., Quebec, Canada). To position the probe in a walnut kernel, a walnut was partially cracked, and a small hole was drilled into the kernel (Fig. 1B). To give a reliable value, the probe must fit into this hole tightly. Four probes were placed in walnuts located in the lower part of the container; the remaining probes were placed in the top layer.

Effect of Moisture Content on Heating Rate

Walnuts were cracked and the kernel and the shell of the nut were separated to determine the moisture content. The kernel was cut into small pieces to facilitate water loss. The initial weight of the kernels and shells of at least 20 nuts per sample was determined. The nuts were placed in an oven at 131°F. The weight of the kernels and shells was determined every other day, until it was steady. The percentage water loss (weight loss) was determined as a percent of the fresh weight. Industrial labs do not distinguish between kernel and shell moisture content and they determine the moisture content of the entire nut. To make the results comparable, *total* moisture contents were calculated by combining the moisture content of the kernel and the shell for each nut.

To increase the moisture content of the walnuts to a higher level for experimental purposes, they were submerged in double demineralized (DD) water for about 8 hours. After submerging the nuts were spread out in harvest bins and placed in a 77°F room with low relative humidity. After 4 days the nuts were transferred to a 95°F room to accelerate the drying process. Nuts were heated in the RF on day 1, 2, 4, 7 and 16, and moisture contents were determined.

Treatment of Infested Walnuts with RF Energy

Walnuts were infested with the most heat tolerant life stage of navel orangeworms at USDA-ARS in Fresno by placing a non-diapausing fifth instar larva in a walnut through a pre-drilled hole in the shell. The holes were sealed with adhesive clay to prevent insects from escaping from the walnuts. The infested walnuts were transported to UCDavis by car.

Table 1. Heating protocols

Treatment	Treatment temp.
A	Control (untreated)
B	116.6°F (47°C)
C	122°F (50°C)
D	127,4°F (53°C)
E	131°F (55°C)

A portion (224) of the infested nuts was not treated and acted as a control (Table 1). The remaining infested nuts (891) were mixed with about 1100 uninfested nuts from the same batch and with the same moisture content. This mixture of infested and uninfested nuts was divided into four lots, and treated with RF until the coldest nut reached a temperature of 116.6, 122, 127.4, or 131°F. The walnuts were held at room temperature before treatment, and were treated directly after transport. Infested walnuts were stored at room temperature for 4 days after treatment before the shells were opened for examination. Insect mortality was recorded; moribund and living insects being kept under observation for a further 2 weeks.

Walnut Quality

To determine the upper limit of walnut tolerance to heating with RF, walnuts were heated to 122, 140, 158, 176 and 194°F with RF. The moisture content of 20 individual nuts was determined before and after heating. A sample of nuts from each heating experiment was stored in a -4°F freezer. Accelerated shelf life tests were conducted in which additional samples of treated in-shell walnuts were stored at 95°F and low relative humidity (RH) for 10 and 20 days. These conditions simulated 1 and 2 year storage periods at 39°F, respectively (Taoukis et al. 1997). Oxidative rancidity involves a reaction with oxygen, increasing as the temperature rises and storage time increases. To test for both oxidative and hydrolytic rancidity in the treated walnuts, oil will be pressed from the nuts (Wang et al. 2001a) and the peroxide value (PV, AOCS 1998a) and the fatty acid value (FA, AOCS 1998b) of the oil will be determined in triplicate for every treatment. In addition, walnut color, internal kernel appearance and sensory quality will be evaluated in heated samples.

RESULTS

Initial tests on heating variability

Tests with glass jars filled with tap water revealed that the center of the electromagnetic field was relatively uniform. The temperature distribution pattern was reproducible when the same amount of tap water was used and when the machine was operated in exactly the same way. However, the overall conclusion was that even within a fluid like water, in which molecules can diffuse freely there was variability in the heating rate. This variability is inherent to the design of the machine that was used, and would be much less of an issue in a conveyor RF system. However, when heating tests were conducted with walnuts, the variability of the RF machine was not considered a significant, disturbing factor, as the heating rate variability was more due to differences in product physiology.

For a second series of tests, a simple device was developed which allowed the rotation of the container during treatment. Rotating the sample container was used to avoid nuts being continuously subjected to the same inequalities of the electromagnetic field. These inequalities combined with differences in nut physiology might cause differences in heating. Several heating experiments were done with or without applying this manual rotation, and results were compared in Table 2. Rotation of the container did not decrease the heating rate variability, and no relationship was found with the average heating rate or the variability (standard deviation) in heating rate. The conclusion was that product factors are more influential in affecting the heating rate than the variation in electromagnetic field.

Table 2. The effect of rotation of the experimental container, a means to mix the walnuts during RF treatment, on the average heating rate (n=8) and the heating rate variability (Standard deviation) of walnuts. std = standard deviation

	Heating rate (°F min^{-1})			
	Rotation		No rotation	
	Average	Std	Average	Std
1	22.1	5.8	17.2	1.4
2	14.1	1.3	15.9	1.5
3	12.3	2.1	14.3	2.2

No clear differences were found in temperatures measured in the upper walnut layer and lower layer during treatment, though vertical temperature stratification was not an issue that was intensively investigated. While mixing the nuts within the container (results not shown) and rotation of the container did not seem to affect temperature variability, much of this heating variability is expected to disappear when RF heating is scaled up and a conveyor belt is added.

Walnut heating

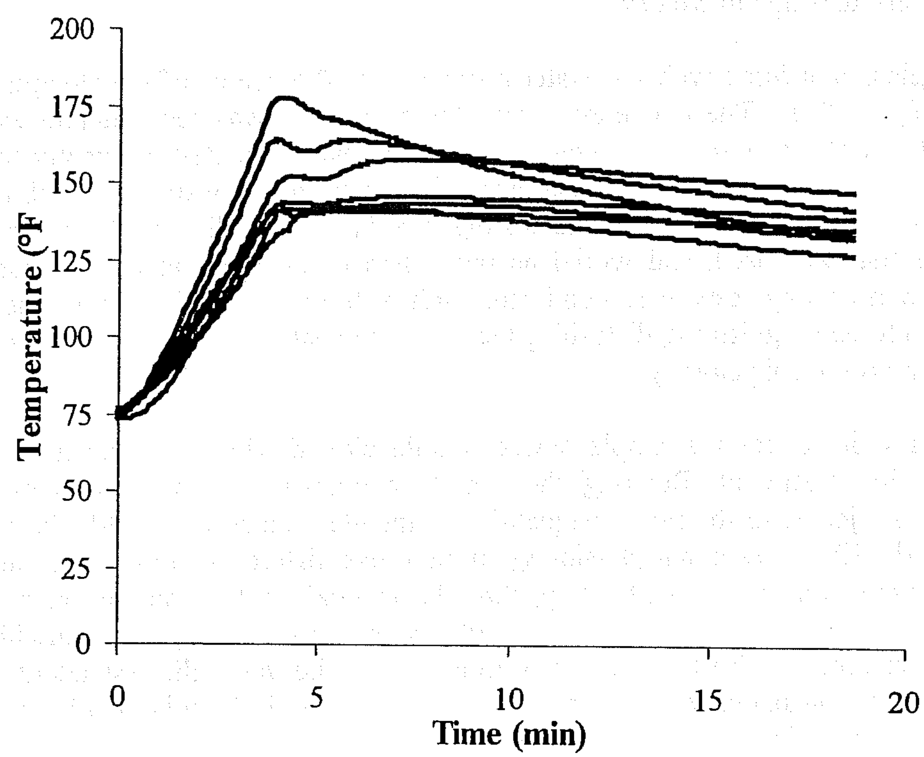


Figure 2. The temperature of 7 walnut kernels was monitored during heating with RF. The total moisture content of the nuts was 8.48 ± 0.46 % (n=20), which is close to the moisture content after washing of the nuts in practice (about 10%). The kernel of the walnut with the lowest heating rate (light blue line) was at 127.4°F after 3.61 min.

Compared to fruits, walnuts heat slower in an electromagnetic field because of their low moisture content. However, using the standard factory settings of the RF machine already led to acceptable heating rates. After we recently changed the factory settings (we changed to tuning of the electrode to increase the power coupling), the heating rates for walnuts were greatly improved. Heating times in Fig 2 could probably be decreased by about a factor of two under the present settings. Because adjustments of the machine were just completed before this report was written, only some preliminary tests were done with the present set-up. Another decrease in heating time would be achieved by an increase in total power available from the equipment. The RF equipment that is normally used in industrial processes have much more power than our test unit (85 kW compared with 12 kW per unit), and will therefore heat walnuts more quickly.

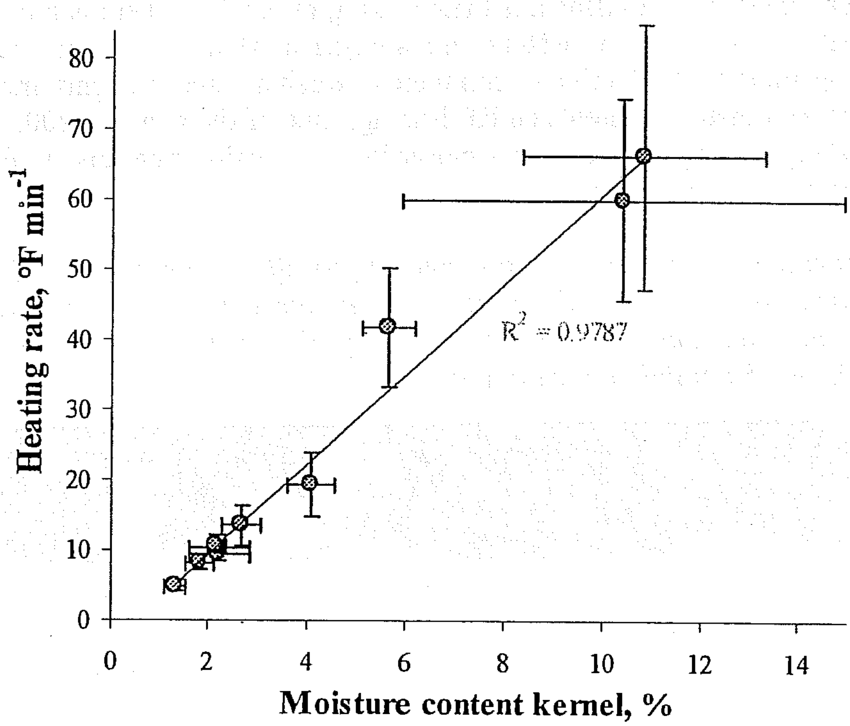


Figure 3. The linear relationship between the moisture content of walnut kernels given in % of the total kernel weight (n=20) and the heating rate during treatment (n=8).

RF technology would only be meaningful for walnut disinfestation if it can kill insects without significantly decreasing walnut quality, taking into account certain safety margins. Not every walnut heats up with the same rate during RF heating. But, every walnut in a batch should be exposed to a certain temperature, probably between 127.4 and 131°F (this is still under investigation), to be sure that all insects are killed. A high variability in heating rate, and thus final temperature, would expose some walnuts to rather high temperatures. For that reason variability in heating rate is an important factor, and it should be kept as small as possible. Fig. 2 shows the heating pattern of walnuts that were submerged in water for 8 hours followed by up to 4 days of drying.

Moisture content and heating of walnuts

Once the variability in the electromagnetic field could be excluded as a potential cause for the heating rate variability during RF heating of walnuts, and it was determined that the heating rate variability was not decreased by mixing the walnuts, the heating rate variability was considered to be due to differences in the moisture content of the nuts.

To investigate the heating rate over a broad range of moisture contents, nuts were submerged in demineralized water, and heating rates were determined after several drying periods. The results of this experiment are summarized in Fig. 3 and Table 3. The relationship between the moisture content and the heating rate of the kernel is a linear one, and the variation in moisture content is