Optimizing Heat Treatments in Food-Processing Facilities

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Locations where heat can be used

- Bins/silos
- Whole-facility treatment
- Specific rooms
- Specific pieces of equipment

Optimizing heat treatments

- Using the right amount of heat energy
- Determining when to stop a heat treatment
  - Achieving 100% kill of insects without adverse effects on structures or equipment

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A successful heat treatment depends on...........

- Estimating the amount of heat required (through heat-loss calculations)
  - KSU Heat Treatment Calculator
- Improving pest management efficacy
  - Eliminating cool spots through uniform heat distribution (use of fans)
  - Assessing pre- and post-heat treatment insect counts
  - Following good exclusion and sanitation practices

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Facilities Subjected to Heat Treatment

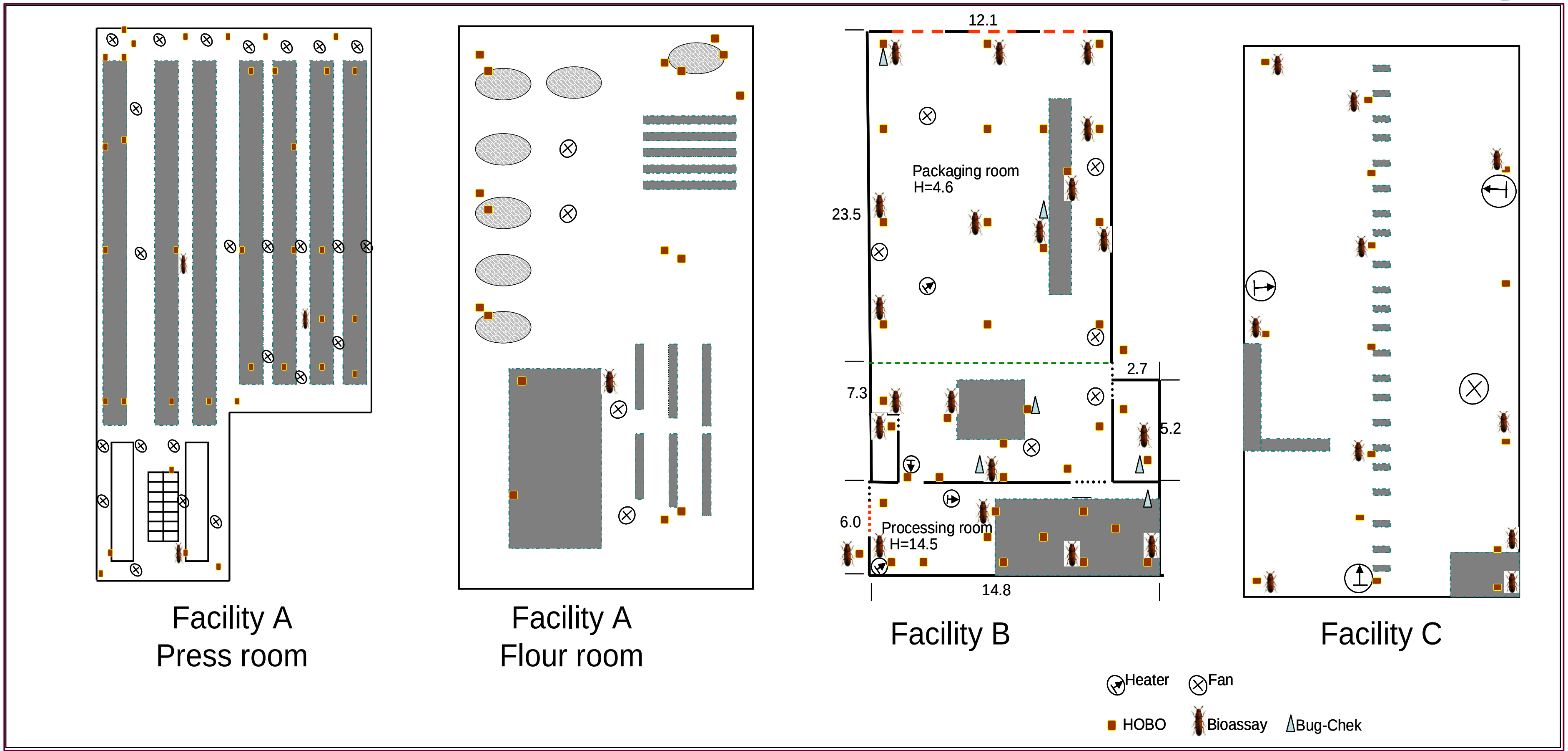
Facility	Product	Area Treated	Heat Source	Heat Treatment Dates
A	Pasta	Press room Flour room	Gas	Jul 1-2, 2006
B	Pet food	Processing and packaging rooms	Steam (new)	Jan 25-26, 2007
C	Ready-to-eat cereals	Corn mill room 8	Steam (old)	Aug 31-Sep 2, 2007

Layout of Facilities

Pasta facility

Pet food

Cereal manufacturing



Facility A
Press room

Facility A
Flour room

Facility B

Facility C

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Pasta facility (A)

- Press area:
- Volume: 1.55 million cu ft
- Surface area: 46,750 sq ft
- Wt of steel: 9,710,00 lb

- Flour room:
- Volume: 120,000 cu ft
- Surface area: 3,600 sq ft
- Wt of steel: 750,000 lb

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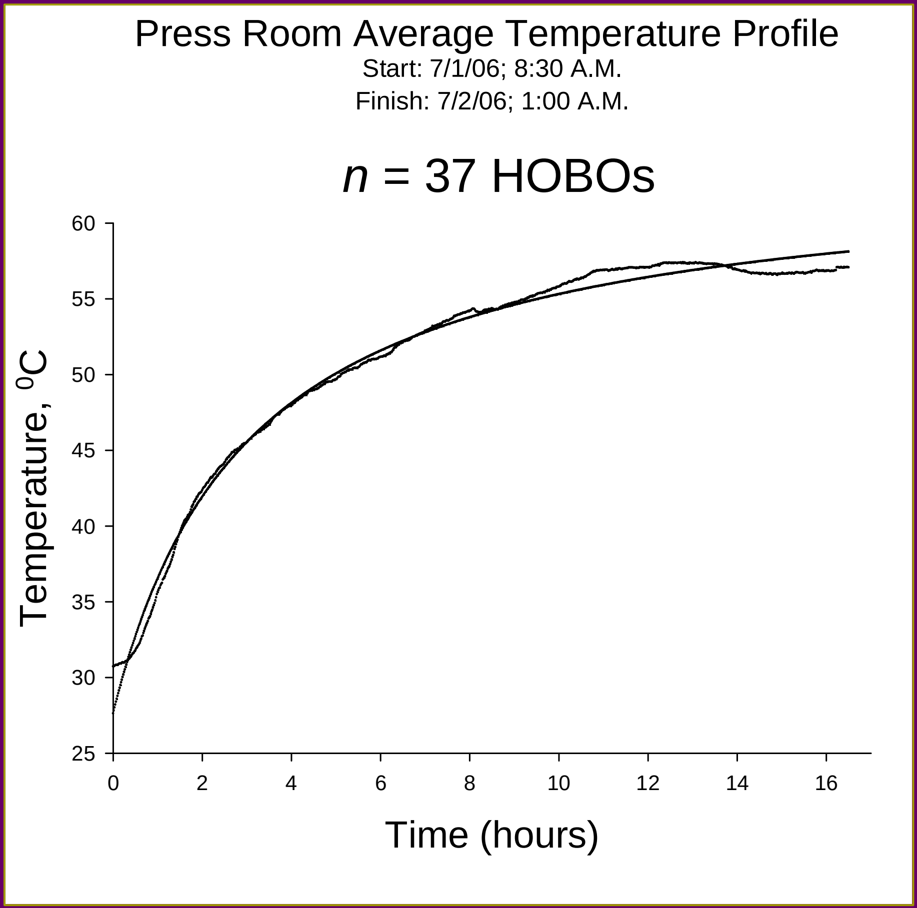
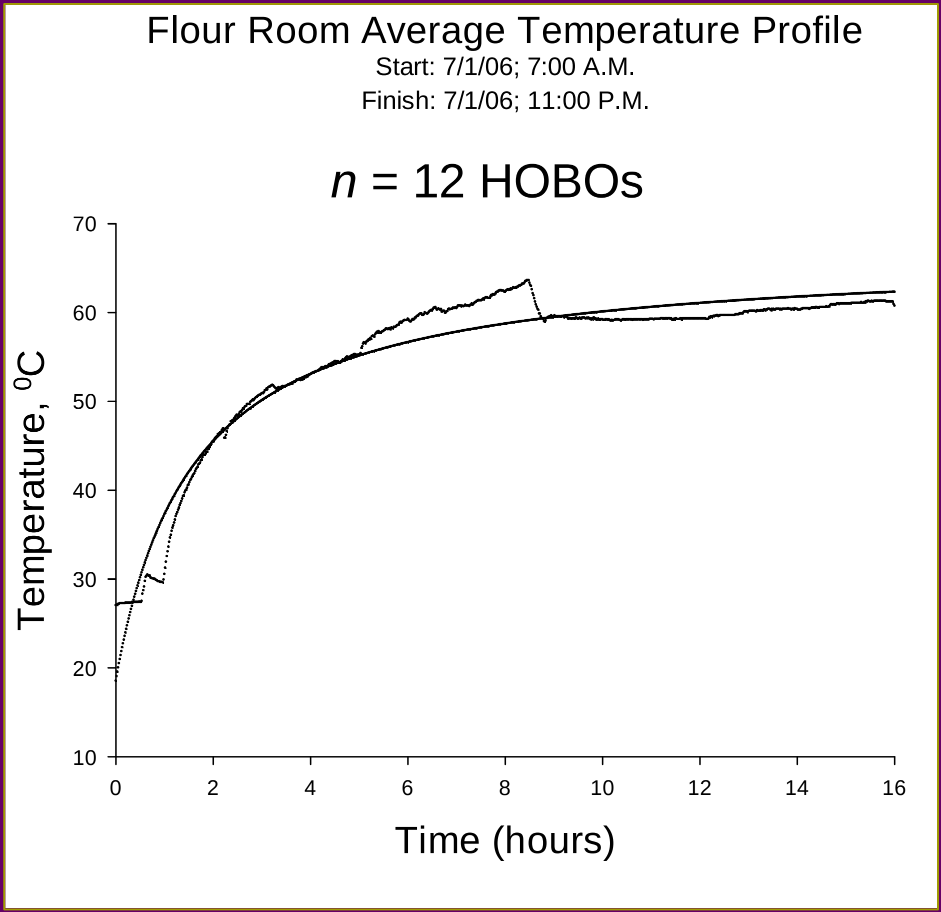
Facility A – Temperature Profiles





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Heat energy requirements based on KSU Heat Treatment Calculator

Area	Heat requirements (in million BTU)			BTU/cubic foot/hour			Natural gas usage (in Therms)		
	Hourly		Total	Rise	Hold	Total	Hourly		Total
	Rise	Hold					Rise	Hold	
Flour Room	1.6	0.7	18.24	13.4	5.8	9.6	21.5	9.8	250.4
Press Room	11.53	4.9	142.6	6.3	2.7	4.6	165	70	2041

Total estimated heat required: 160.8 million BTU. Estimated fuel cost: $ 2498

Heat generated at 70% efficiency: **155 million BTU**
Natural gas used during heat treatment: **2212 Therms**
Cost of fuel used during heat treatment: **$ 2411**

Storgard® DOME™

- Improvements
  - Integrated components
  - Locking mechanism
  - Precise to specification
  - Reliable, convenient lure holder
  - Stackable

Captures of Red Flour Beetles (*Tribolium castaneum*)

Mean number of adults/trap/week

Date	Press room (*n*=35)	Flour room (*n*=10)	Outside (*n*=5)
5/30/2006	0.46	0.40	0.50
6/14/2006	0.20	0.42	0.65
6/28/2006	0.32	0.65	0
7/11/2006	0 (100%)	0.09 (86%)	0
7/25/2006	0.03	0.10	0.38
8/8/2006	0	0.05	0.50
8/23/2006	0.01	0.05	0.20

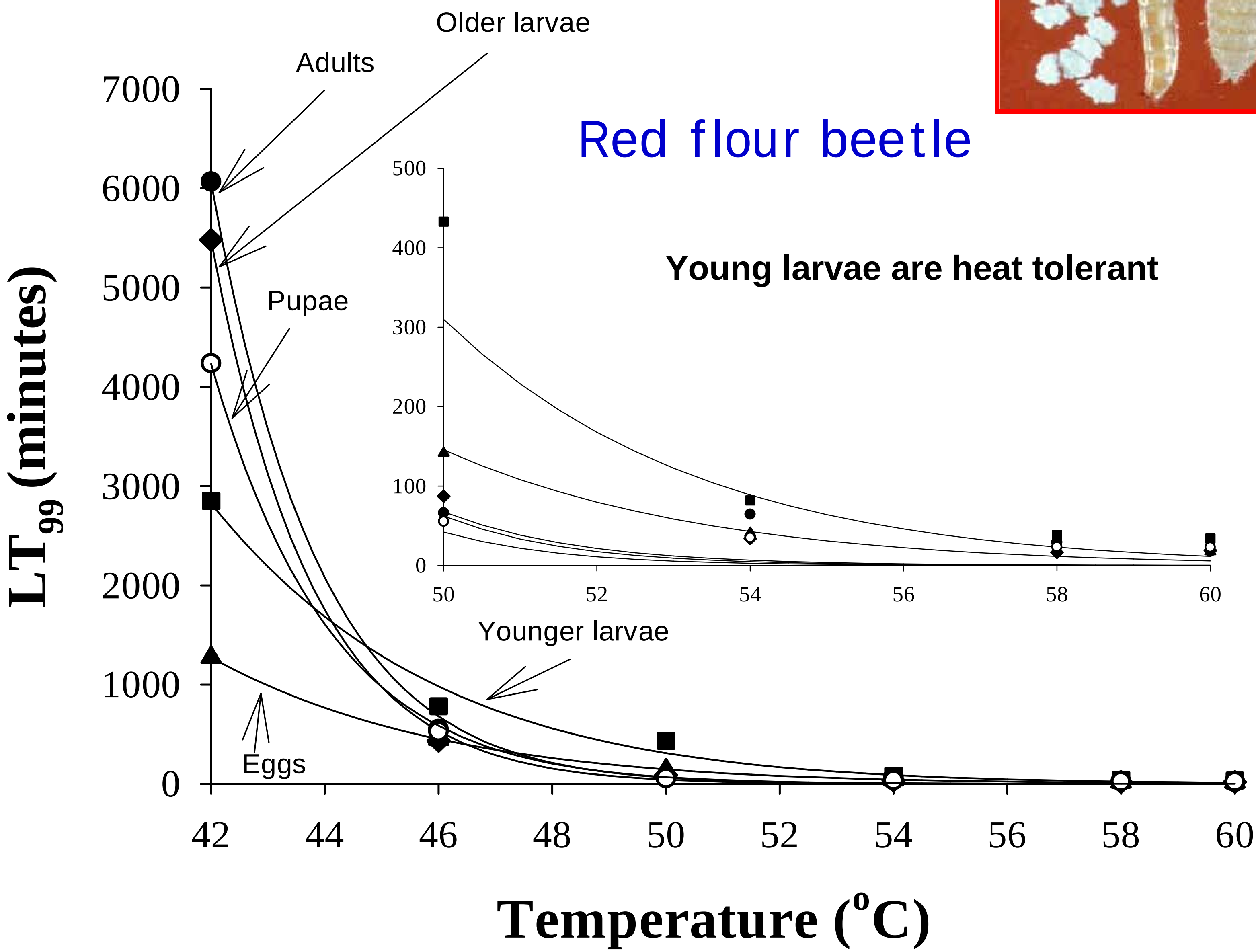
Captures of Warehouse Beetles (*Trogoderma variabile)*

Mean number of adults/trap/week

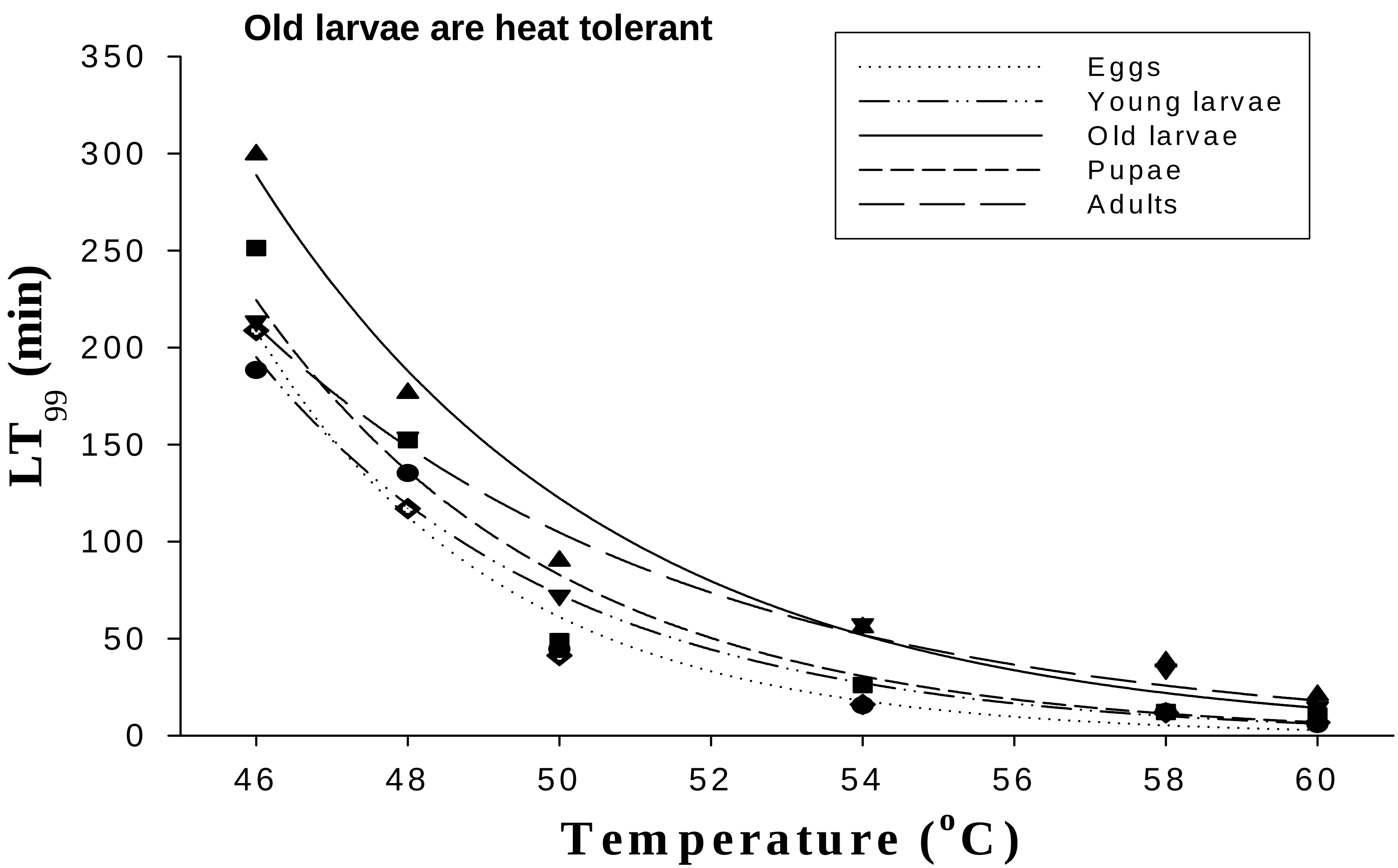
Date	Press room (*n*=35)	Flour room (*n*=10)	Outside (*n*=5)
5/30/2006	0.40	0.05	26.90
6/14/2006	0.47	1.40	35.00
6/28/2006	0.34	1.62	39.74
7/11/2006	0.03 (91%)	0 (100%)	53.90
7/25/2006	0.12	0.15	69.88
8/8/2006	0.10	0.20	18.90
8/23/2006	0.06	0.00	36.00

Can you predict mortality of heat tolerant stages of an insect species during heat treatment?

Red flour beetle



Confused flour beetle



Thermal death kinetic model for the most heat tolerant stage

$$\log_{10}\left(\frac{N_{t-dt}}{N_t}\right) = \frac{dt}{D(T_t)}$$

where $N_{t\text{-}dt}$ is the survival at $t\text{-}dt$ time interval N_t is survival at time t upon integration equation becomes

$$\int_0^t \log_{10}\left(\frac{N_{t-dt}}{N_t}\right) = \int_0^t \frac{dt}{D(T_t)}$$

$$\log_{10}\frac{N_o}{N_t} = \int_0^t \frac{dt}{D(T_t)}$$

$$\log_{10}\frac{N_t}{N_0} = -\sum_0^t \frac{dt}{D(T_t)}$$

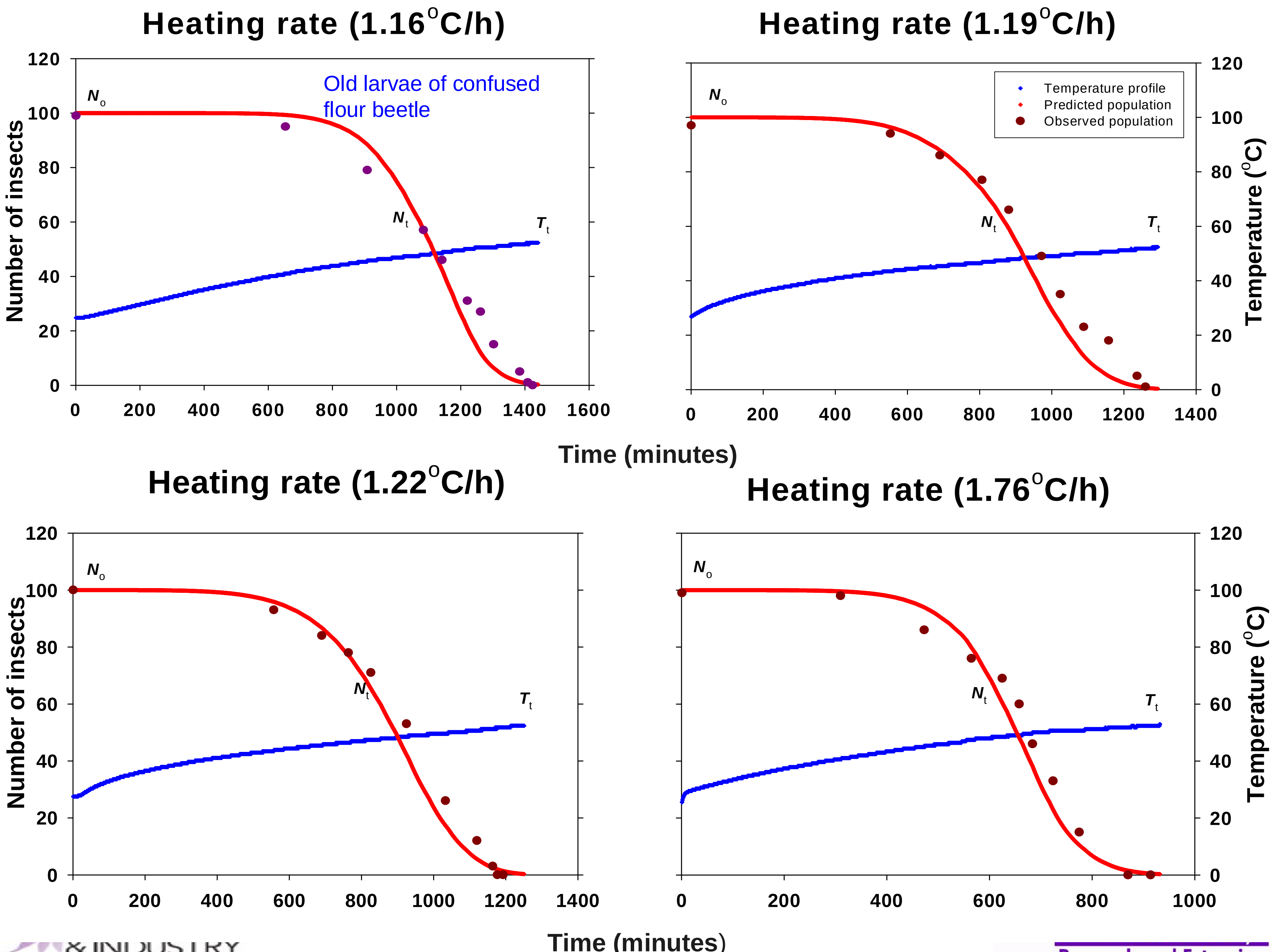
Boina, Subramanyam, & Alavi (2008)

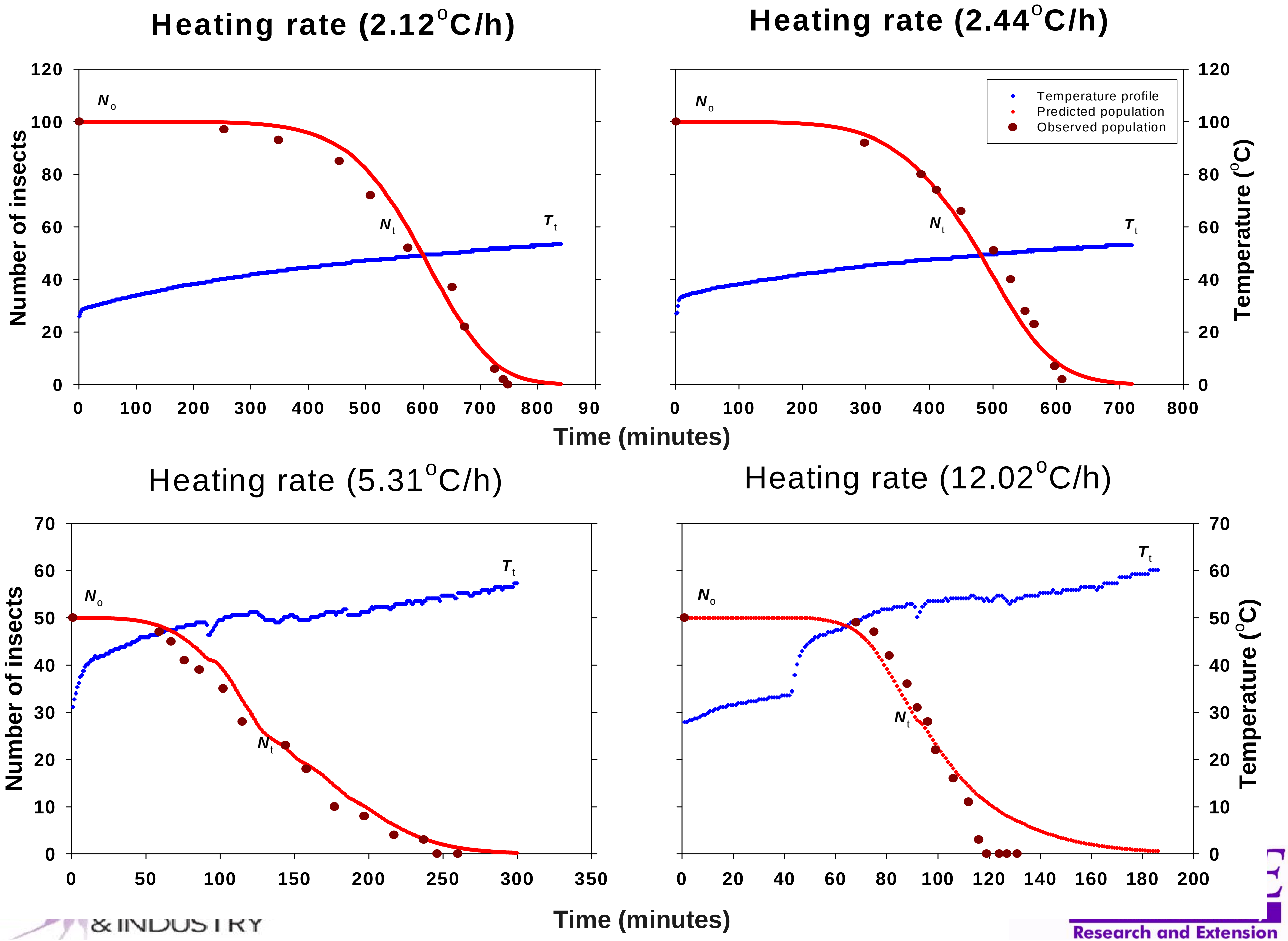
$$N_t = \frac{N_0}{10^{\sum_0^t \frac{\Delta t}{D(T_t)}}}$$

where N_o is the original number of insects; N_t is number of larvae at time t; Δt is the incremental exposure time (1-min), D is the mean instantaneous D-value as a function of temperature (T_t), and T_t is time- dependent temperature profile

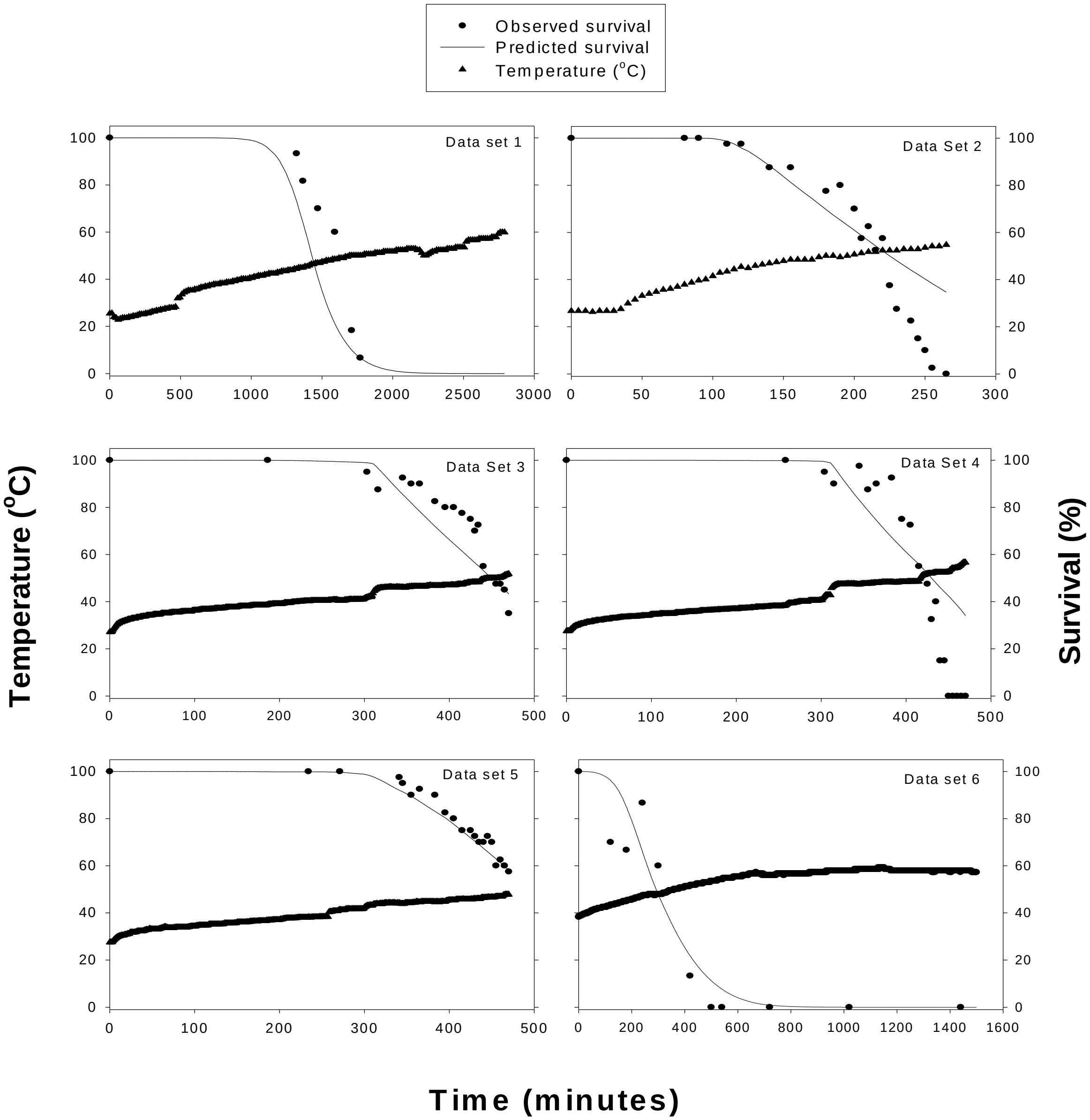
Survival of old larvae of *Tribolium confusum* as a function of temperature

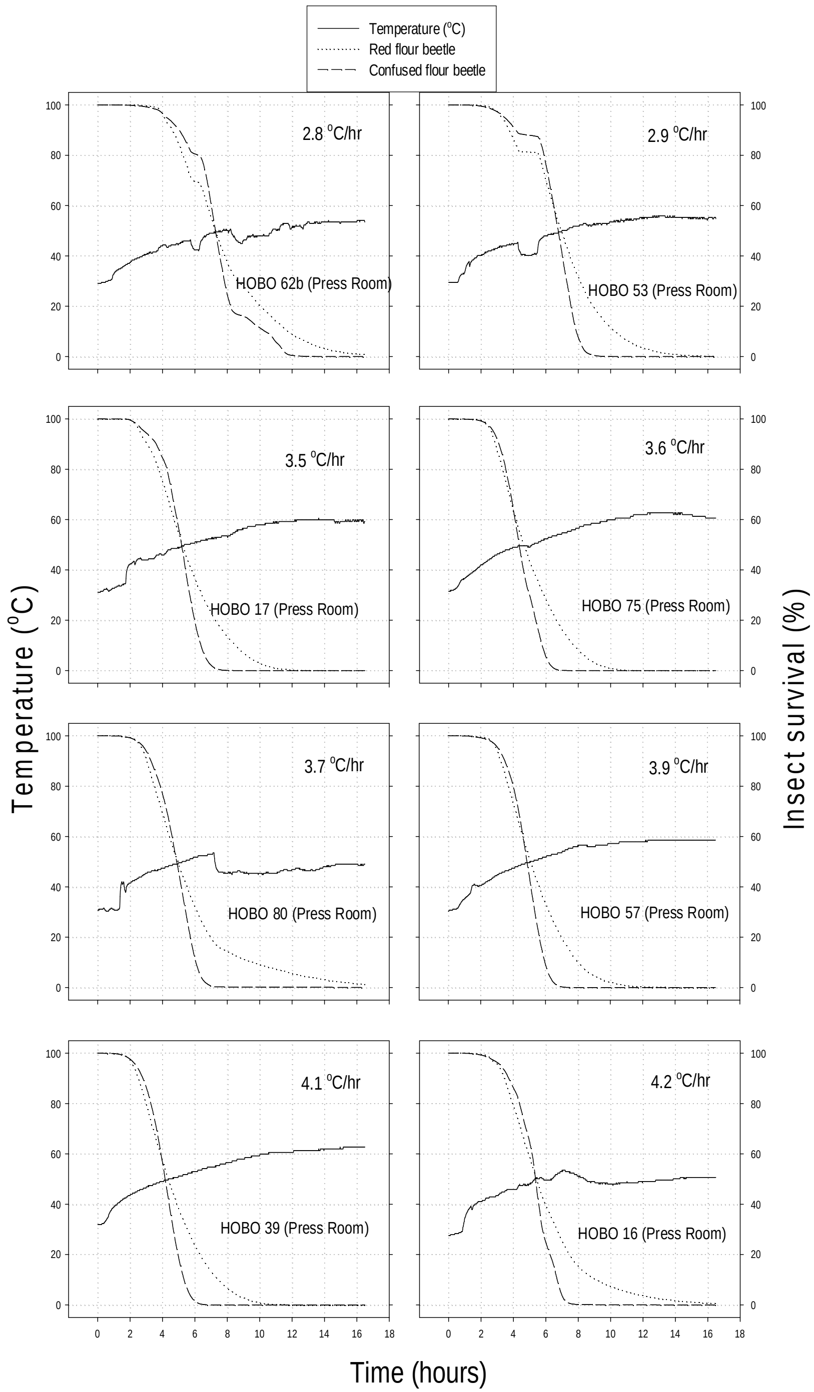
Comparison of model predictions to actual
Insect survival


Heating rate (1.16°C/h)
Heating rate (1.19°C/h)
Heating rate (1.22°C/h)
Heating rate (1.76°C/h)
Old larvae of confused flour beetle
Temperature profile
Predicted population
Observed population
Number of insects
Temperature (°C)
Time (minutes)
N_o
N_t
T_t
0
20
40
60
80
100
120
200
400
600
800
1000
1200
1400
1600


Heating rate (2.12°C/h)
Heating rate (2.44°C/h)
Heating rate (5.31°C/h)
Heating rate (12.02°C/h)
Number of insects
Temperature (°C)
Time (minutes)
Temperature profile
Predicted population
Observed population
N_o
N_t
T_t

Observed and predicted survival of red flour beetle young larvae (Subramanyam & Mahroof, unpublished)





Predicted survival of young larvae of *Tribolium castaneum* and Old arvae *of T. confusum* in a pasta plant (Facility A)

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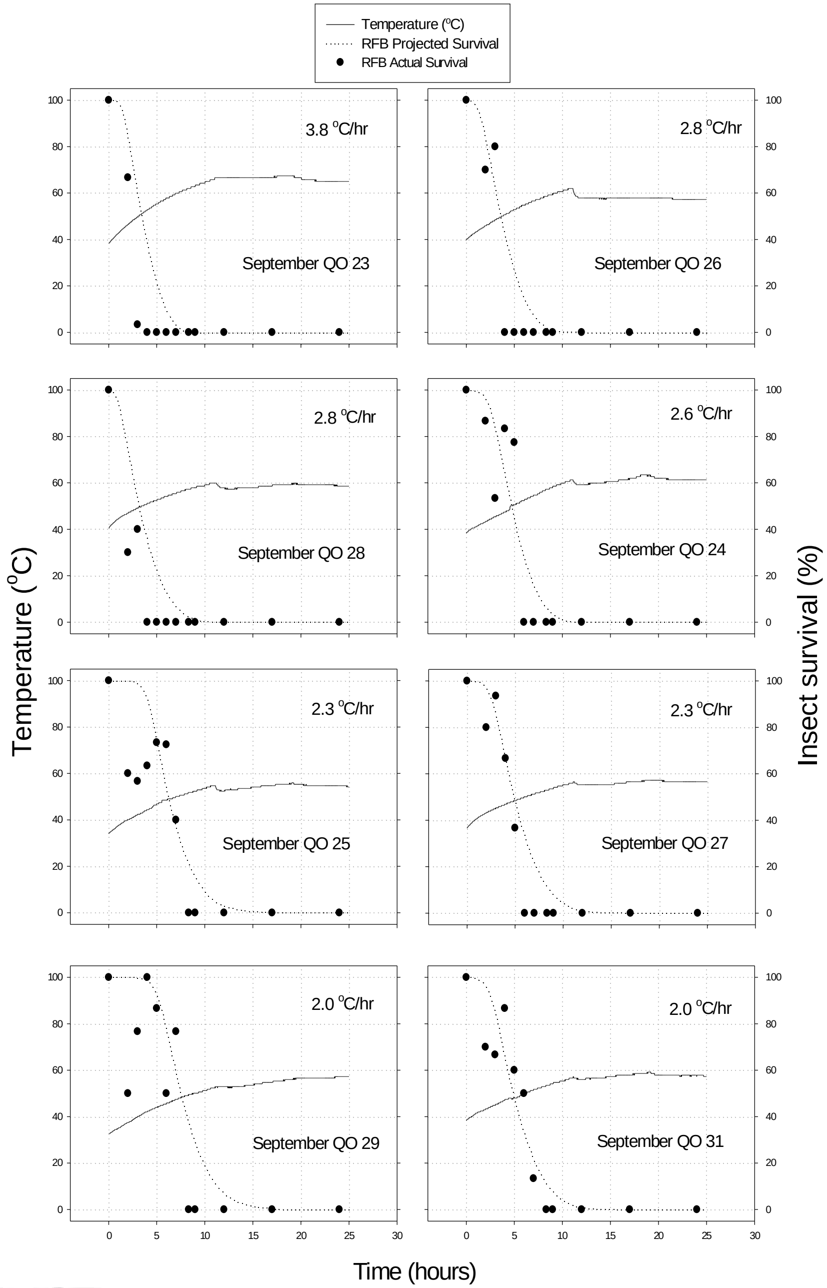

Observed and predicted survival of young larvae of *Tribolium castaneum* in a breakfast cereal plant (Facility C)

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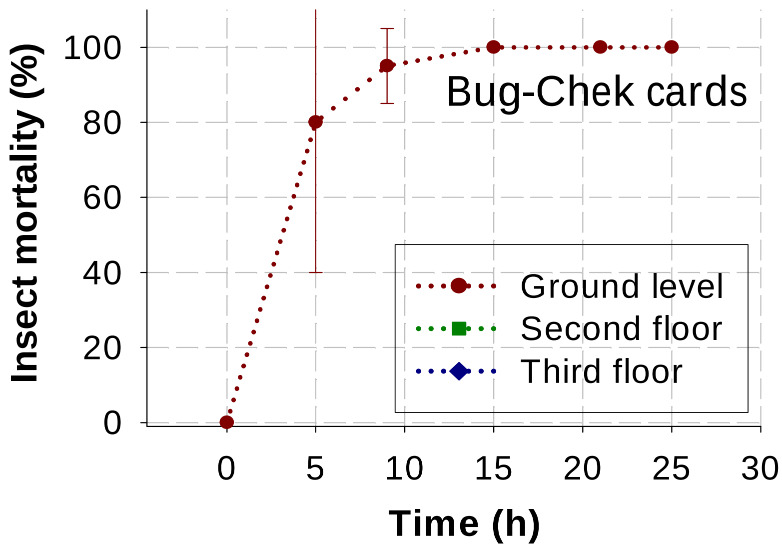
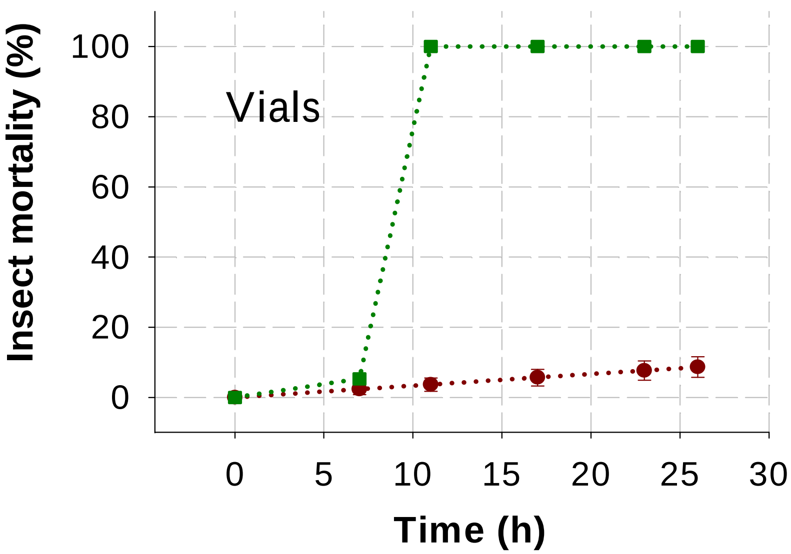
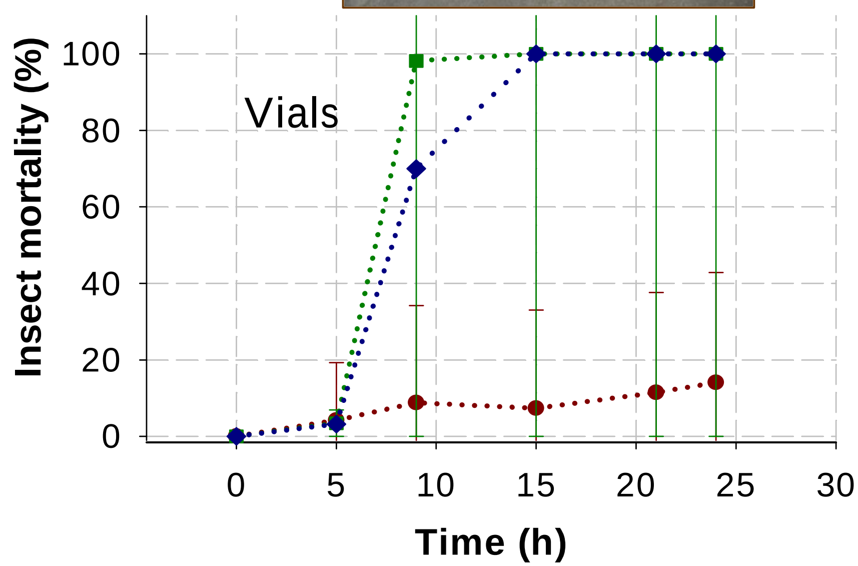
- Are Bug-Chek cards good indicators of treatment effectiveness?

Mortality of Red Flour Beetles (*Tribolium castaneum*) in Vials and Commercial Bug-Chek Cards

Facility (B)







- Factors affecting insect mortality

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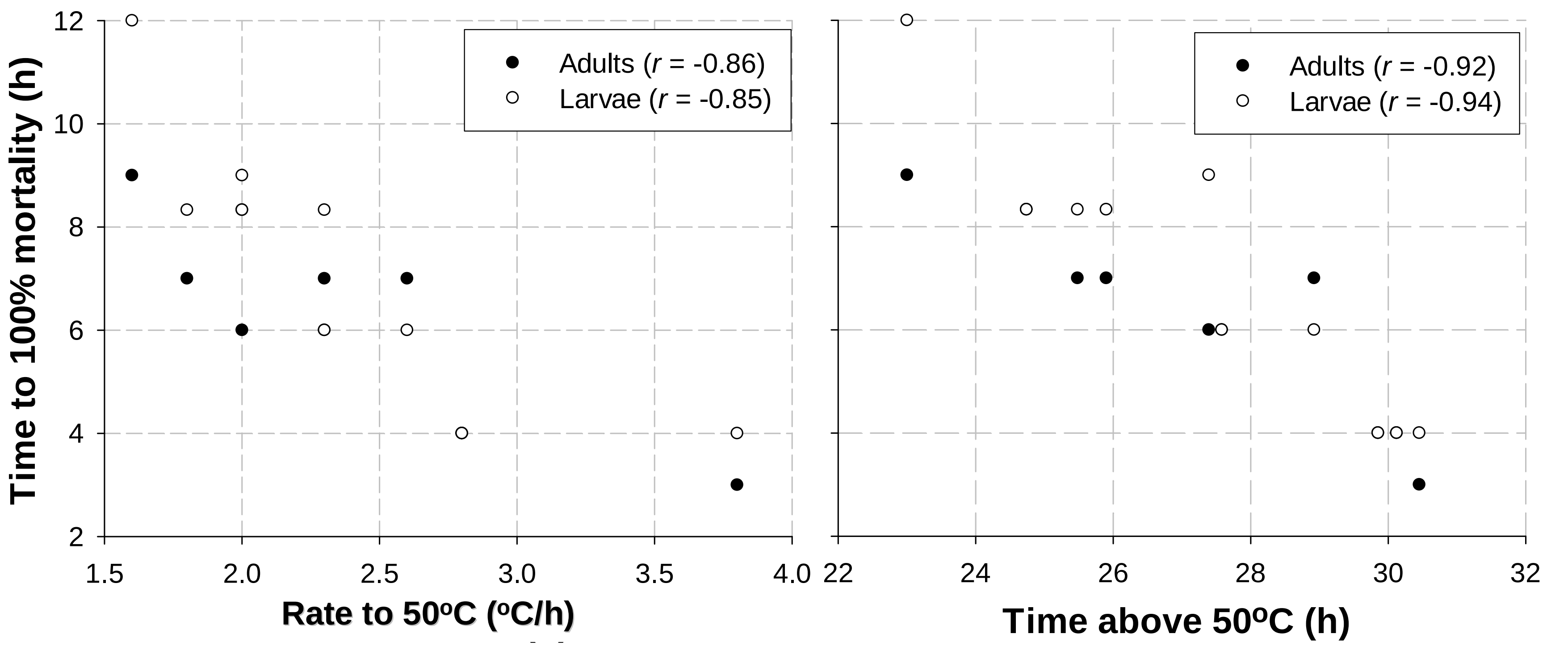
Factors affecting insect mortality (Facility C)

Red flour beetles



There is an inverse relationship between insect mortality and each of the two factors

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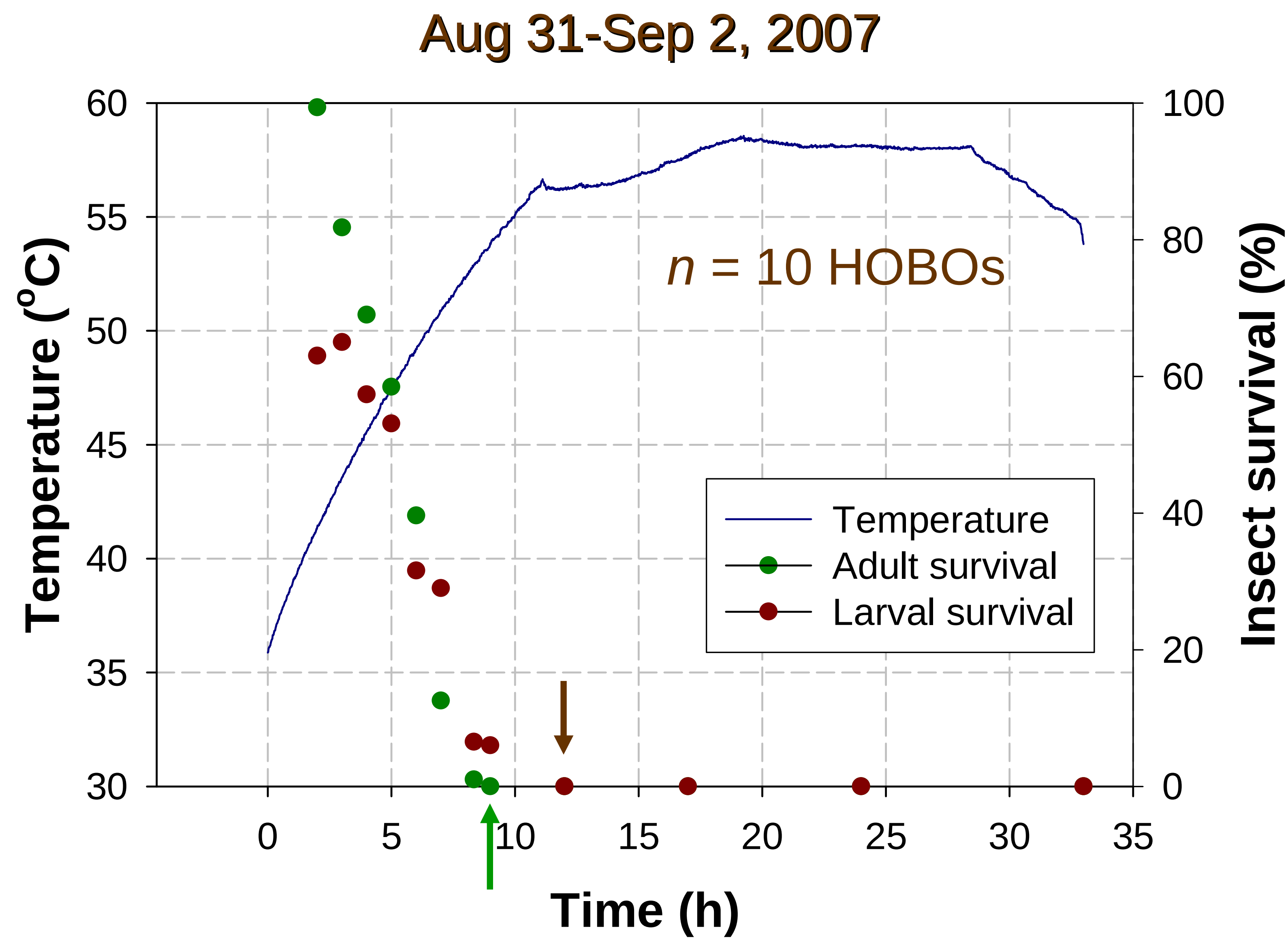
Facility C: Do we need a long exposure time?



- Predicting insect survival or mortality during a heat treatment

- Integrating remote temperature monitoring with the thermal death kinetic model
  - Take corrective action in “real time”

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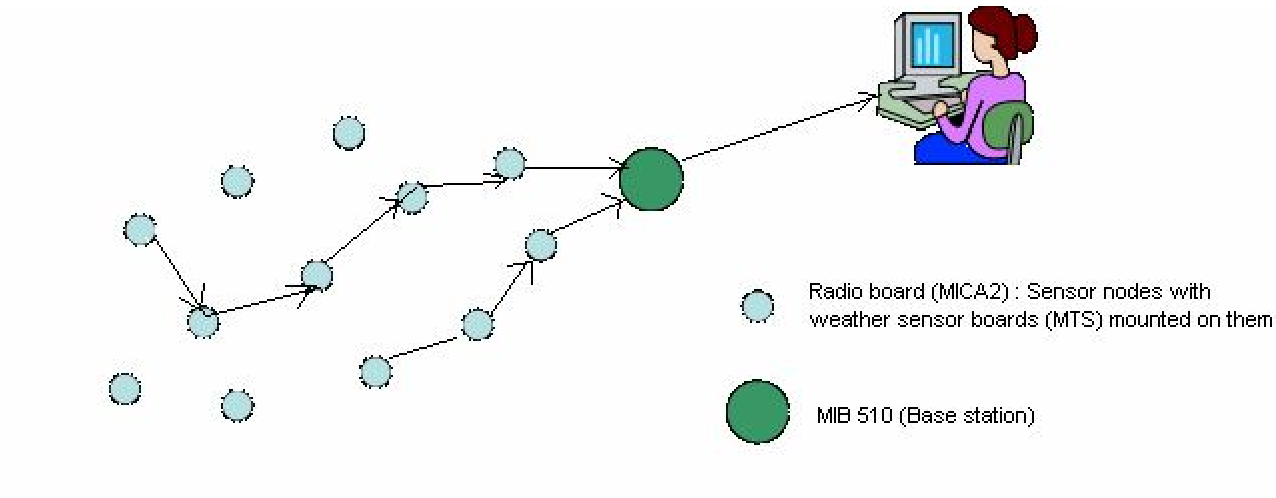
Wireless sensor networks



Typical wireless sensor network architecture

MIB/MICA2/MTS technology from Crossbow Technology Inc, San Jose, CA

MICA2 Processor/Radio board
MPR 400 CB

MTS weather sensor boards (MTS 400 CB)

MIB510 Serial interface and programming board (Base station for wireless sensor networks)

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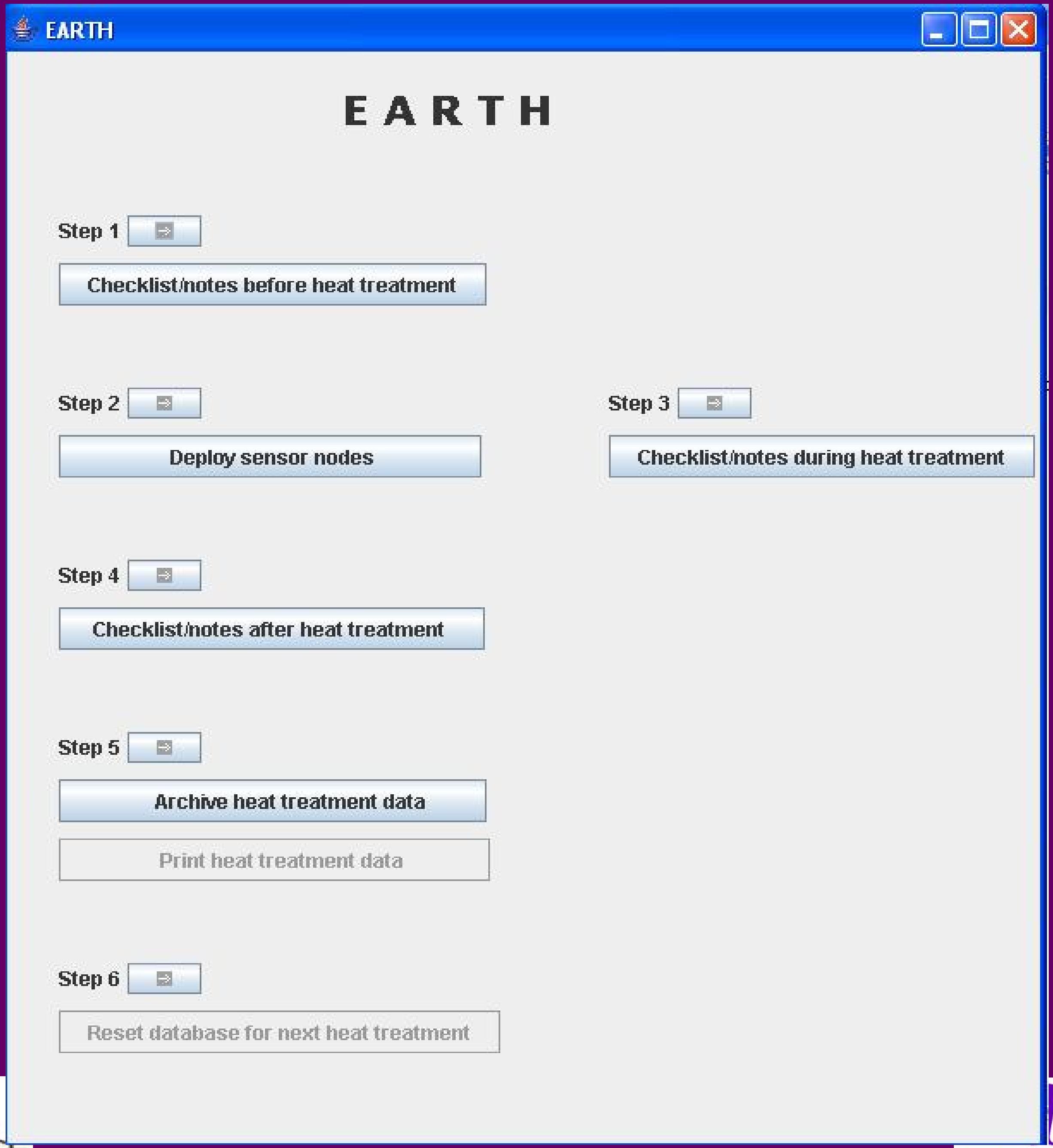
E.A.R.T.H. Software

Efficacy Assessment in Real Time during Heat treatment



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Step 1: Checklist/notes before heat treatment

Step 1 : Checklist/notes before heat treatment

Contact information

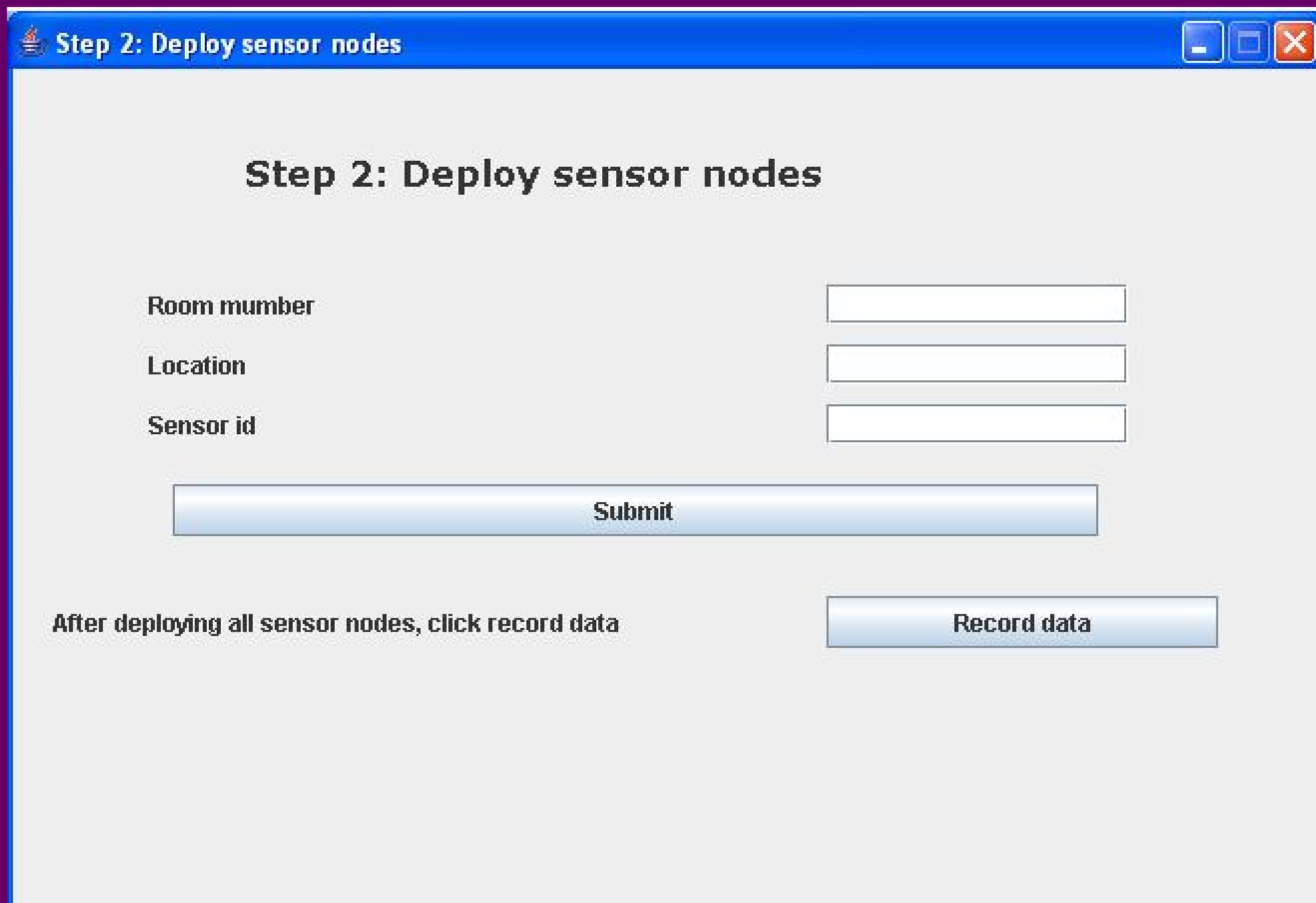
Company name	KSU flour mill
Employee name	Dr. Subramanyam Bhadriraju
Address	Kansas State University, Manhattan, Kansas-66506
Telephone number	785-532-4092
Fax number	785-532-4017
E-mail address	sbhadrir@ksu.edu
Website	http://www.oznet.ksu.edu/grsc_subi

Heat treatment information

Start date (mm/dd/yy)	02/18/2006
Start time (hh/mm/ss)	15/30/00
Time heaters are turned on (hh/mm/ss)	15/35/00
Number of sensors	1
Target species	Red flour beetle (young larvae)
Number of insects (initial)	100
Target temperature (°C)	60
Room temperature (°C)	39
Room humidity (%)	45
Measured by	Thermometer

Observations

Comments



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Step 3: Checklist/notes during heat treatment

Step 3: Checklist/notes during heat treatment

Observations

Comments

Save

Suggested checklist during heat treatment

- Before heaters are turned on, walk through the facility with the heat treatment team to determine whether the facility is ready for the treatment. Determine whether the level of sanitation is adequate and ensure that all the critical items have been removed from the facility.
- Measure the examine temperatures from as many locations as possible within the facility to identify cool as well as over-heated areas. Areas with temperature exceeding 60 deg C (140 deg F) should be lowered within the target zone immediately.
- Elevate temperature outside and around the infested area and move elevated temperatures inwards toward the infestation to kill insects and prevent them from escaping the treated area.

Step 4: Checklist/notes after heat treatment

Step 4: Checklist/notes after heat treatment

End date (mm/dd/yy)	02/19/2006
End time (hh/mm/ss)	15/40/00
Time heaters are turned off (hh/mm/ss)	15/30/00
Room temperature (°C)	60
Room humidity (%)	20

Observations

Comments

Save

Suggested post-heat treatment checklist

- Discontinue heating after the desired exposure time and temperature are achieved. Keep air movers running during and after shutting down the heaters.
- Uncover roof/wall vents, air intakes, and other openings for exhaust air. Open screened windows.

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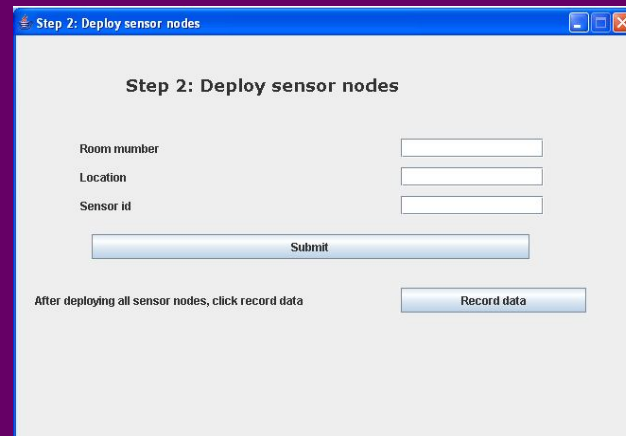
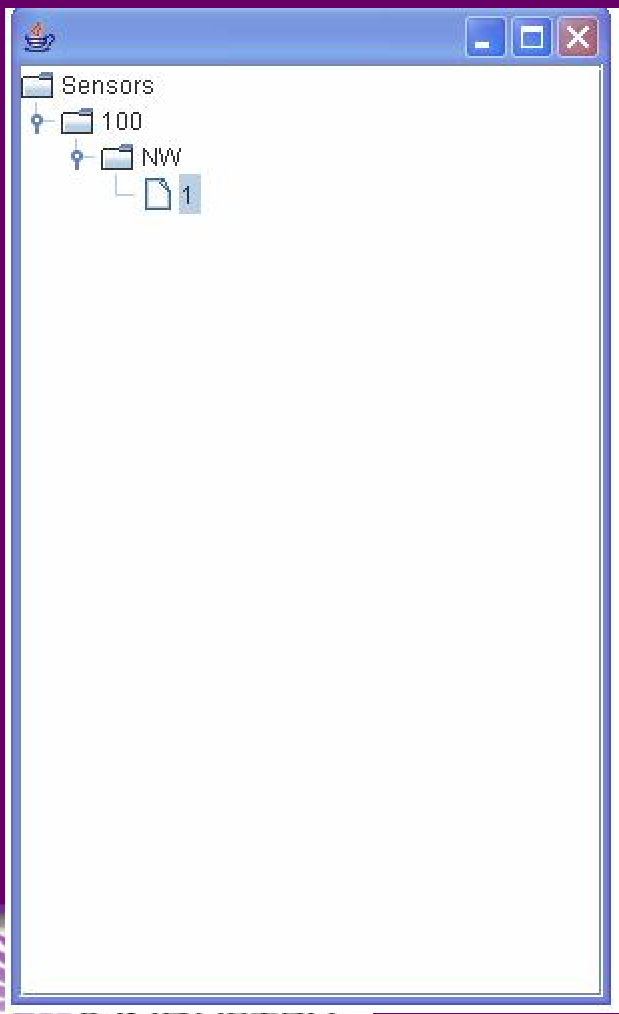
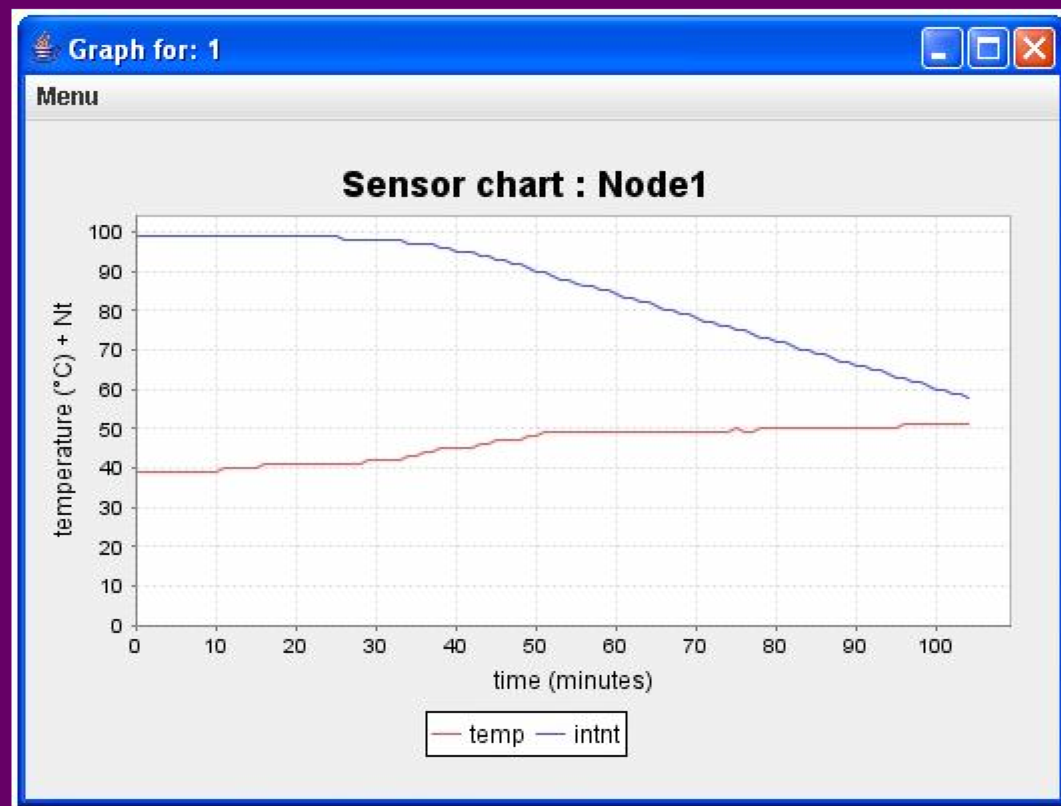
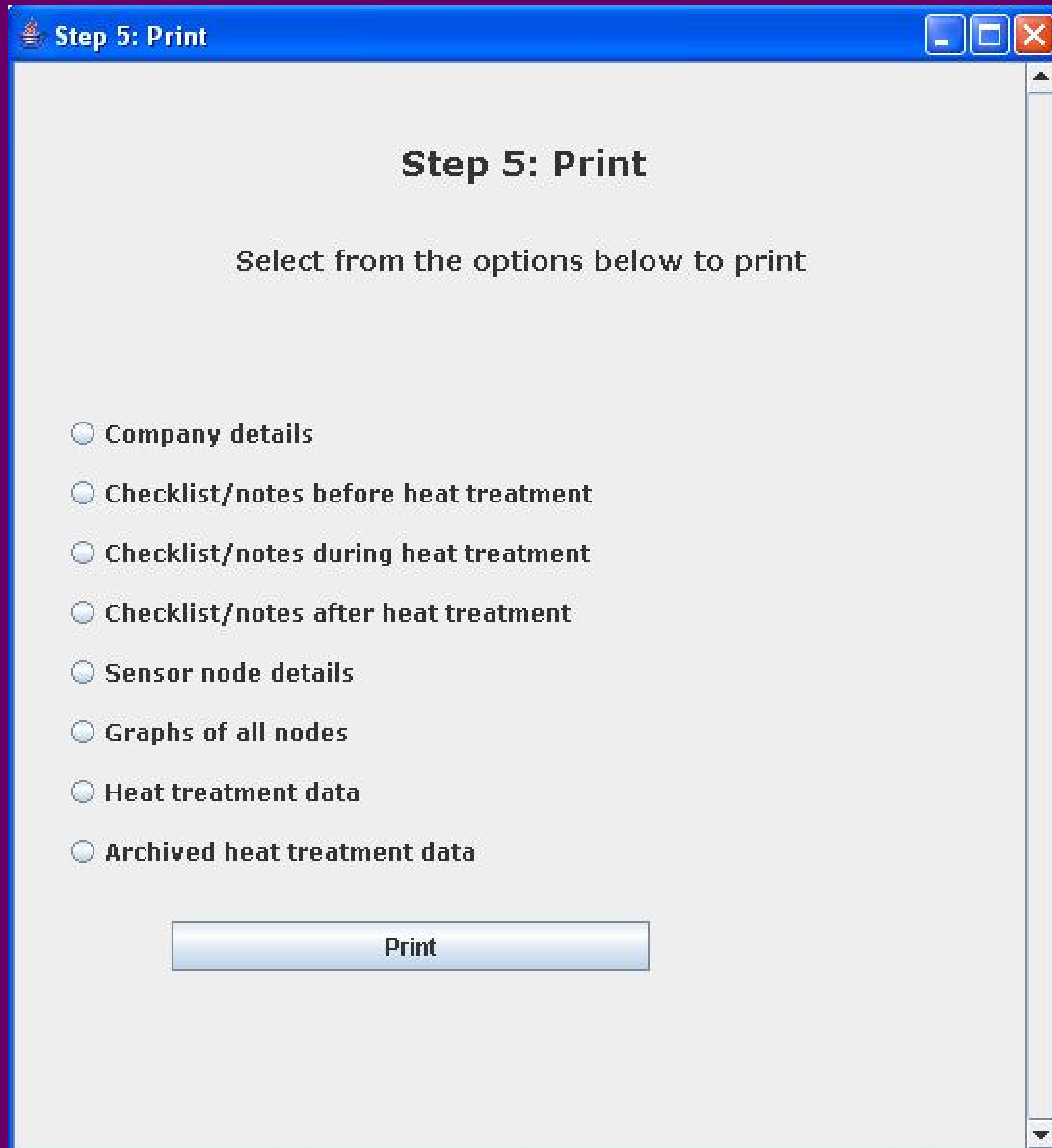
Graph of sensor nodes (tree view)









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Heat treatment data

Generated on : 02/25/2008 13:37:27

Company information

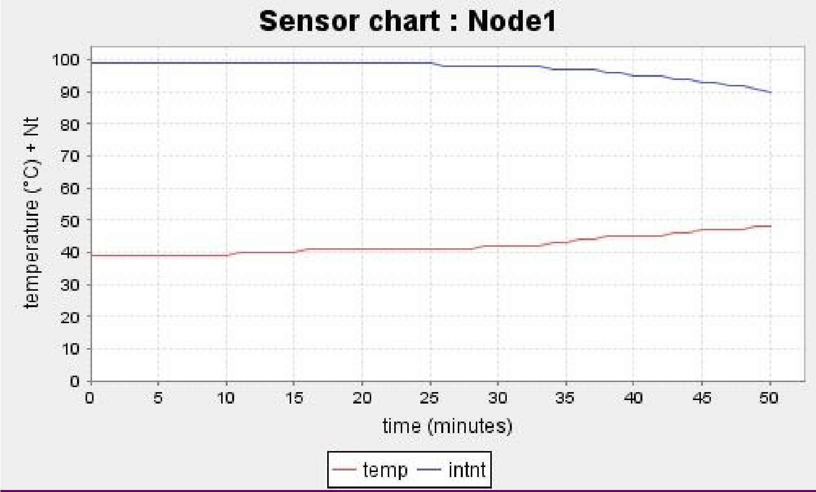
Company name : KSU flour mill
Employee name : Dr. Subramanyam Bhadriraju
Address : Kansas State University, Manhattan, Kansas-66506
Telephone no : 785-532-4092
Fax number : 785-532-4017
Email address : sbhadrir@ksu.edu
Website : http://www.oznet.ksu.edu/grsc_subi

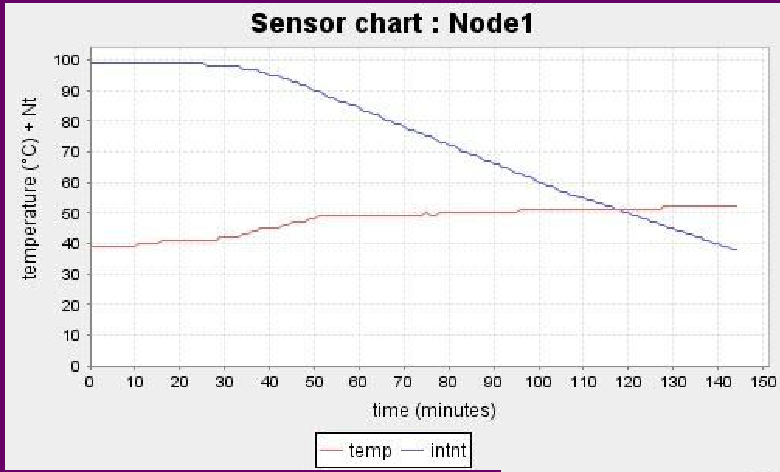
Checklist/notes before heat treatment

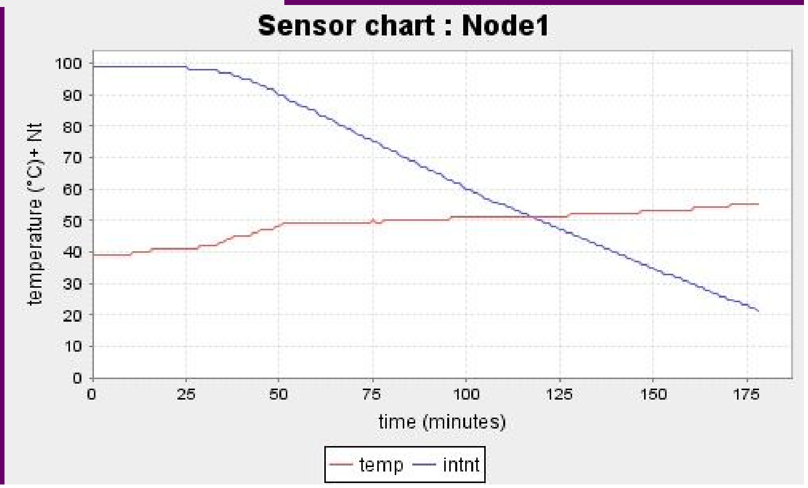
Start date : 02/18/2006
Start time : 15/30/00
Time heaters turned on : 15/35/00
No sensors : 1
Species : Red flour beetle (young larvae)
No insects : 100
Target temperature (°C) : 60
Room temperature (°C) : 39
Room humidity (%) : 45
Measured by : Thermometer

Checklist (pre-heat treatment)

Yes : Appoint site heat-up planning team (including engineer). Elect a team leader to coordinate the effort.
Yes : Identify specific areas to be heated and make site plan. Determine local heat/air sources
Yes : Identify heat sensitive structure and supports, including roofs. If protection or engineering assurances can not be







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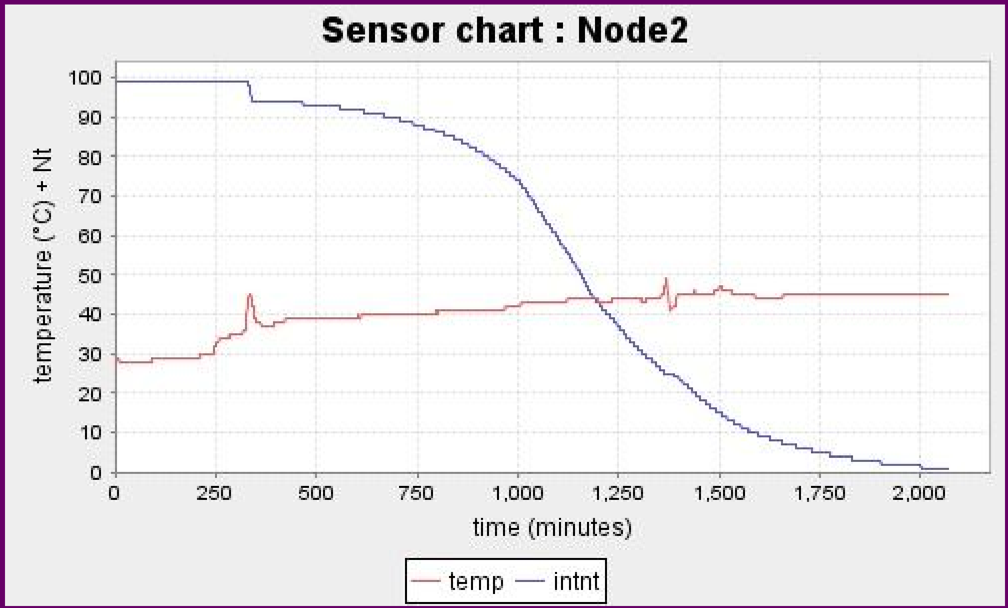

Location: Milling facility, Dept. of Grain Science and Industry
Date: 05/12/2008
Total time: 35 hours
Heat rate: 0.54℃ /hour
Species: *Tribolium castaneum* young larvae

Additional Work

- Validate performance of software predictions during heat treatment of K-State pilot flour mill and commercial mills
- Determine "user-friendliness" of the program
- License technology

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Thank you