A novel method for analyzing grain facility heat treatment data

Hulya AKDOGAN
Mark CASADA
Alan DOWDY
Bh. SUBRAMANYAM

A novel method for analyzing grain facility heat treatment data
~ Introduction ~

- Management of Stored Product Insects (SPI) in grain processing facilities (chemical methods versus high temperatures)
- Heat treatment - a viable alternative to chemicals
- Target temperature $\geq 50^{o}C$, typically 50^{o} to $60^{o}C$
- Temp., duration of exposure, species, stages of development, RH determines insect survival.

A novel method for analyzing grain facility heat treatment data ~ Materials/Methods (1/2) ~

- Pilot flour mill & cleaning house at KSU (6/99 & 8/99)
- Two heating systems: gas & electric
- Gas heating: heaters outside the building; hot air delivered inside the building through nylon ducts
- Electric heating: heaters within the building; power & monitoring cables running outside the building
- Fans used for uniform temperature distribution
- Time/temperature/RH recorded every 10 min at floor level; 16-22 data loggers per room.

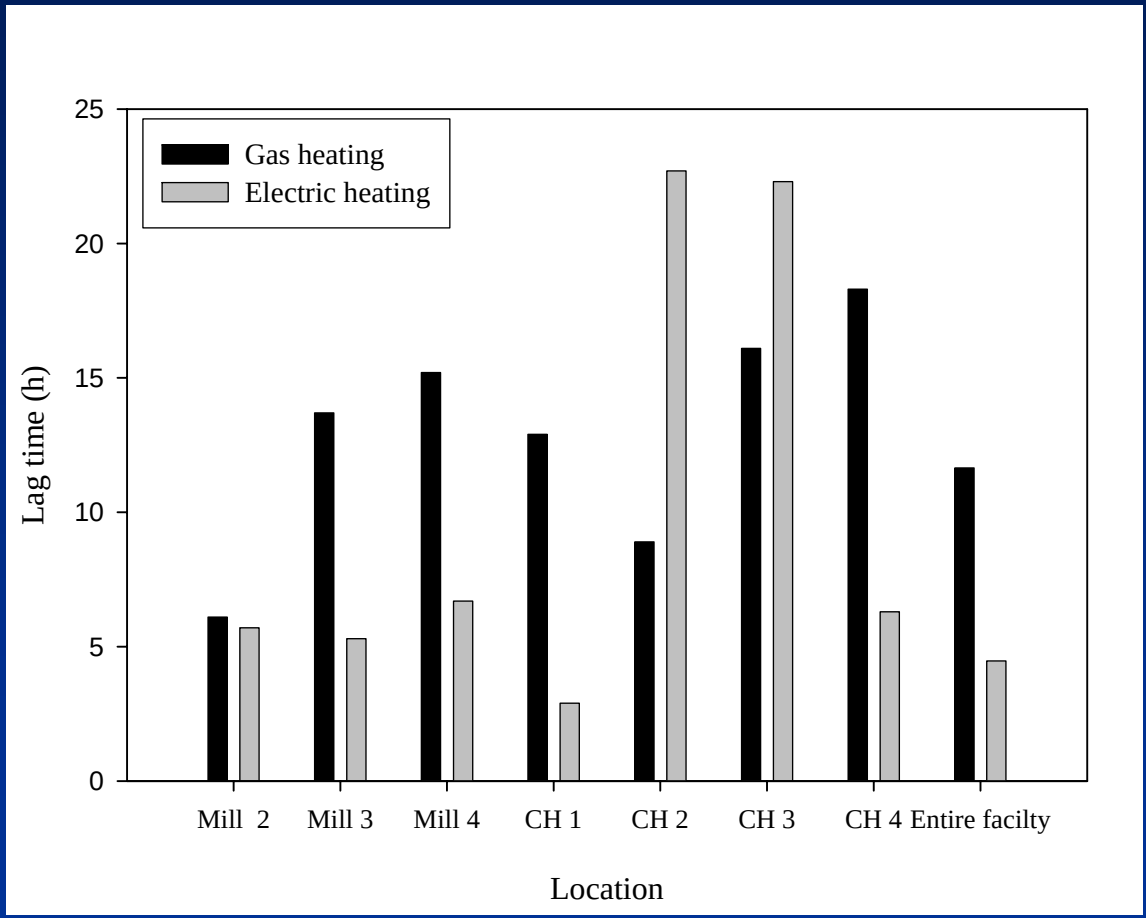
A novel method for analyzing grain facility heat treatment data ~ Materials/Methods (2/2) ~

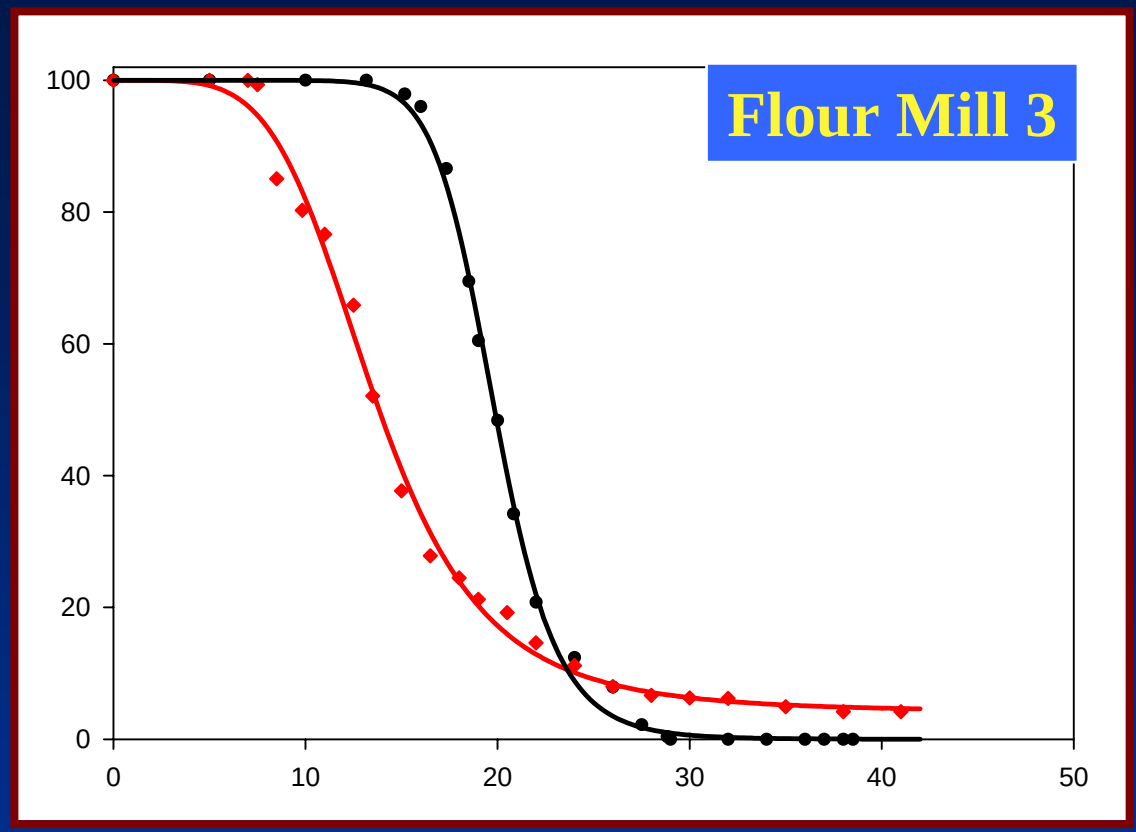
- Effectiveness of heat treatments compared by surface area method
- Surfer software used to calculate the surface areas
- % floor surface area < 50^{o}C as a function of time (duration of the heat treatment) and % floor surface area maximum floor temperature
- Contour maps of maximum floor temperature

A novel method for analyzing grain facility heat treatment data ~ Results ~

- Different heating patterns

Lag times (time delays)





Red- electric heating
Black- gas heating

A novel method for analyzing grain facility heat treatment data
~ Results ~

The surface area approach

- Surface areas calculated from *Surfer* outputs
- Normalized % surface area values for easy comparison

$$A_{norm} = \frac{A(t) - A_i}{A_f - A_i}$$

- A_{norm} is the nondimensional area under 50°C
- A(t) is the percent area < 50°C at time t
- A_i is the % area < 50°C at the beginning of heat treatment
- A_f is the % area < 50°C at the end of heat treatment.

- Nonlinear regression - PROC NLIN procedure (SAS)

A novel method for analyzing grain facility heat treatment data
~ Results ~

The surface area approach (ctd.)

- A log-logistic equation used:

$$Percent\ Surface\ Area = \frac{1}{1+e^{-b((\log_{10} temperature)-c)}}$$

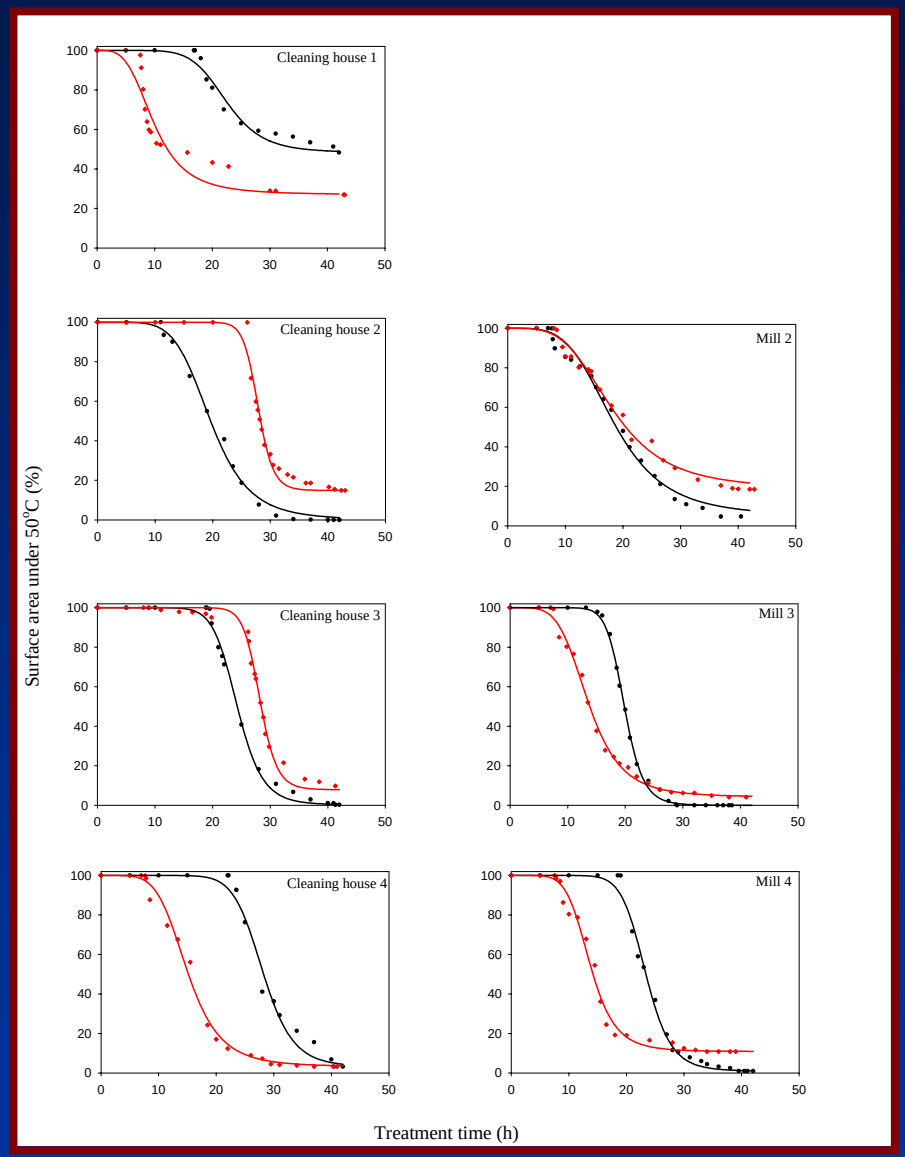
- Pseudo-R^2 calculated. Ranged from 0.90-0.99.

$$Pseudo\ R^2 = 1-\left(\frac{SSR}{SST}\right)$$

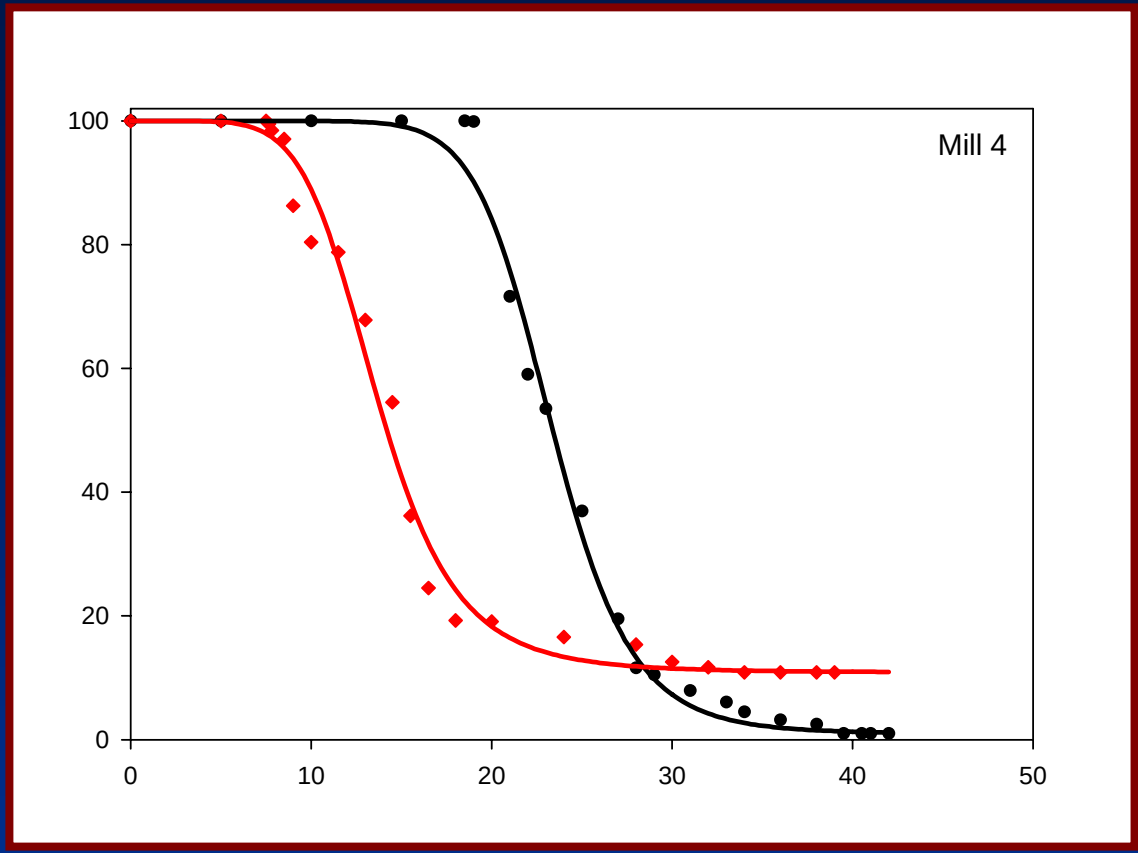
SSR= Residuals Sum of Squares

SST=Total Sum of Squares

Duration of treatment vs. % floor surface area < 50°C

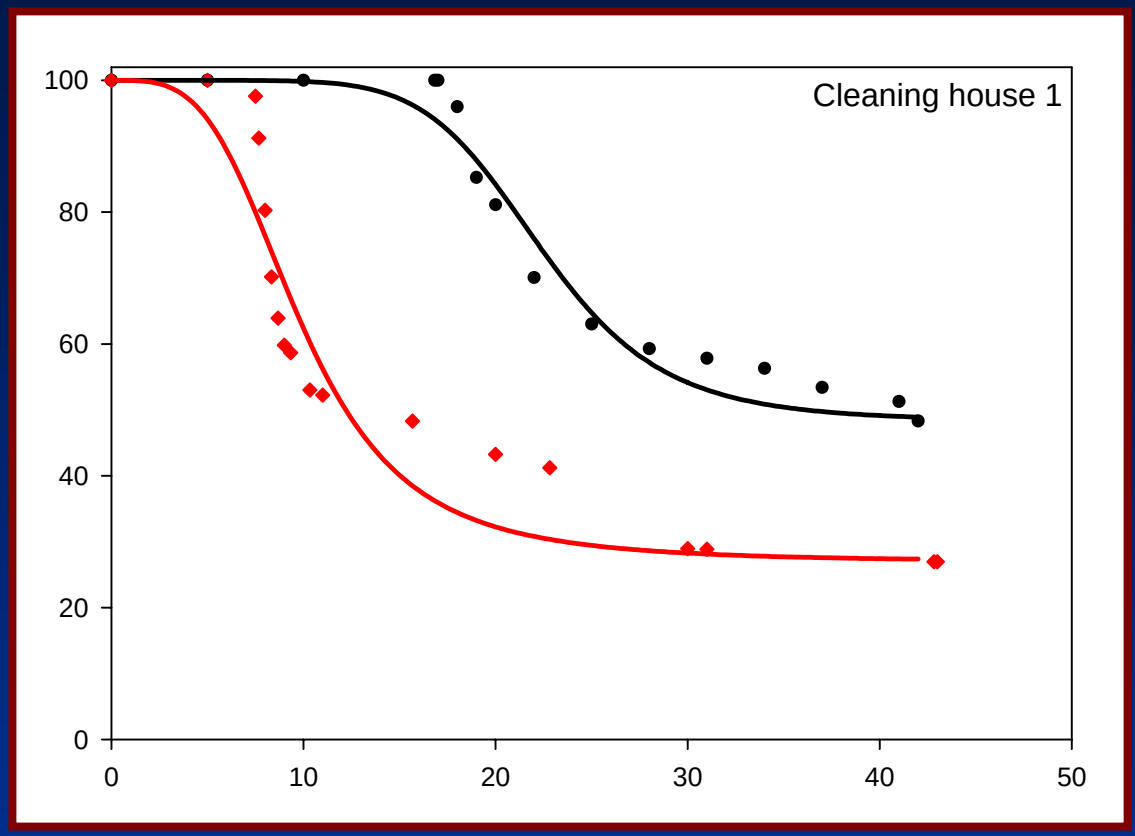


Flour Mill 4



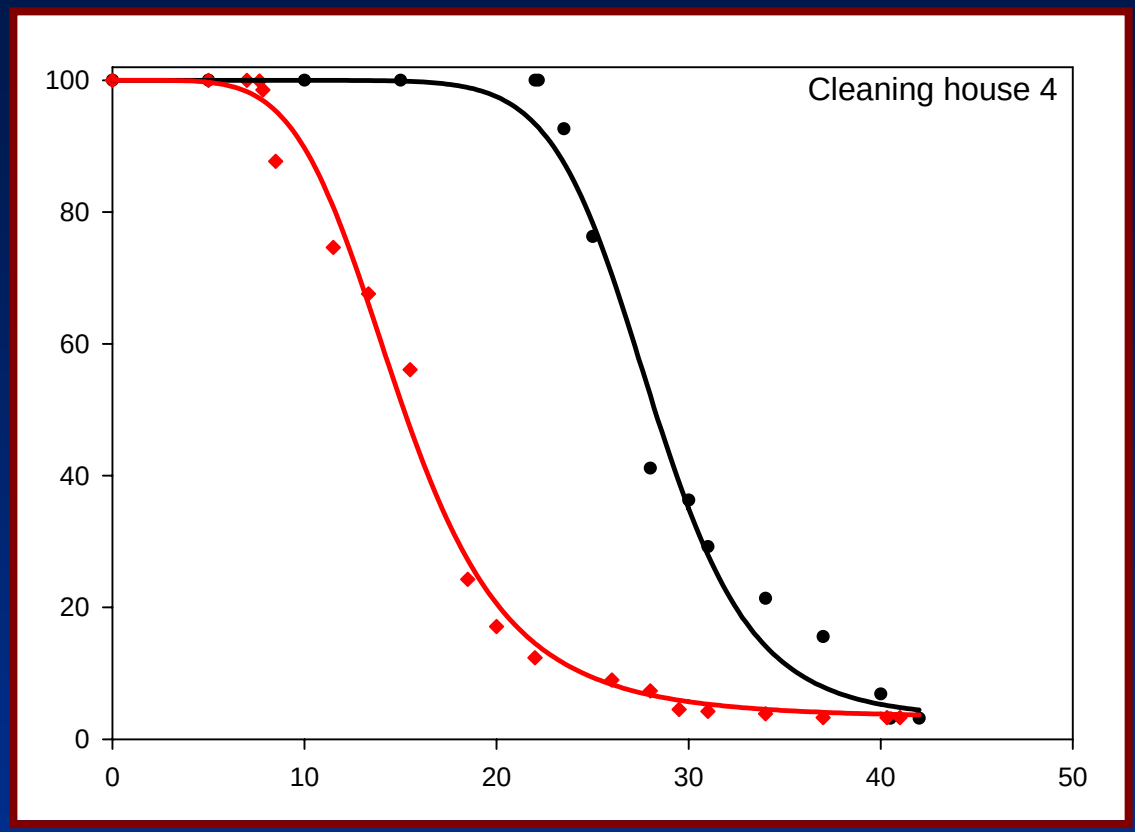
Red-electric heating
Black-gas heating

Cleaning house 1



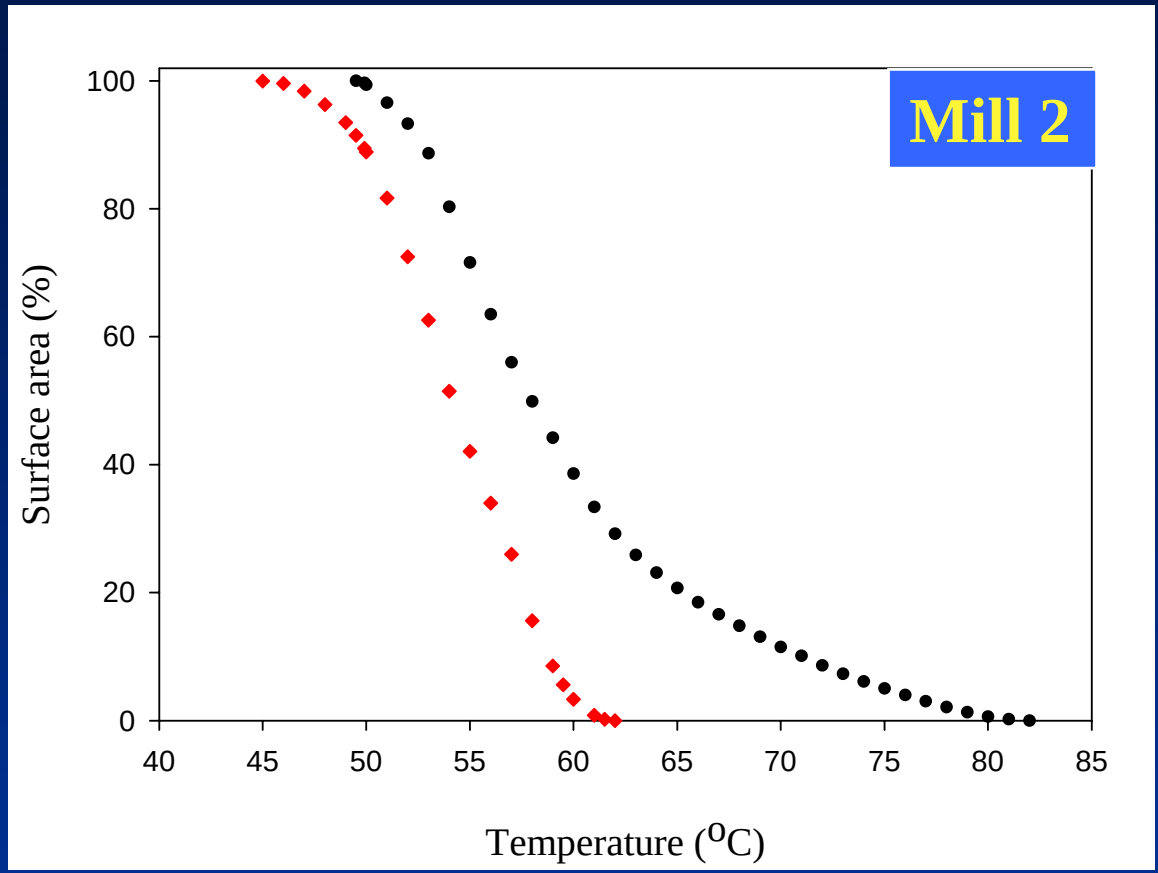
Red-electric heating
Black-gas heating

Cleaning house 4



Red-electric heating
Black-gas heating

Max. floor temp. vs. % floor surface area



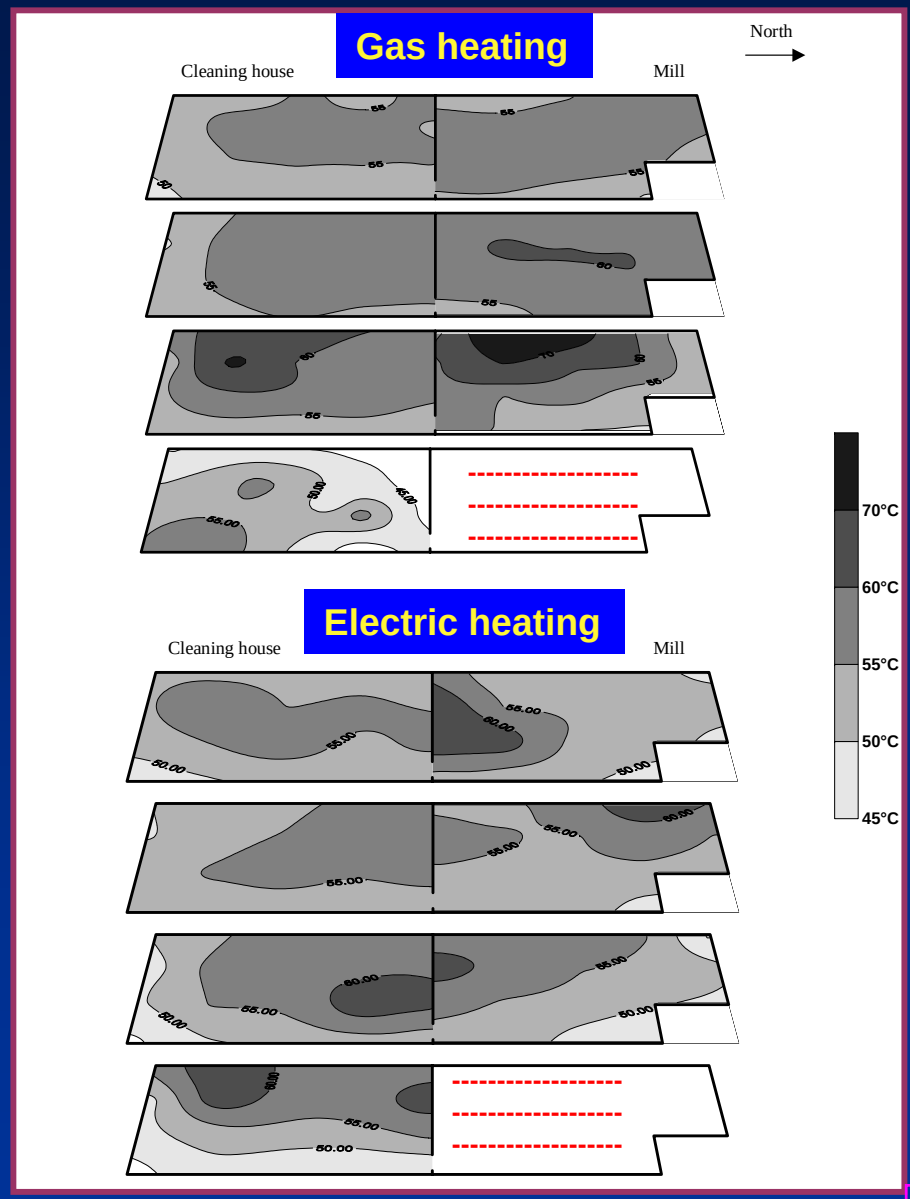
red-electric heating
black-gas heating

A novel method for analyzing grain facility heat treatment data
~ Results ~

- Time delays (lag times)
  - Gas heating
    - slower at the beginning
  - Electric heating
    - mostly shorter compared to gas heating
- Effectiveness of treatment ($T<50^{o}C$)
  - Gas heating
    - less under-heated areas observed
  - Electric heating
    - more under-heated areas observed

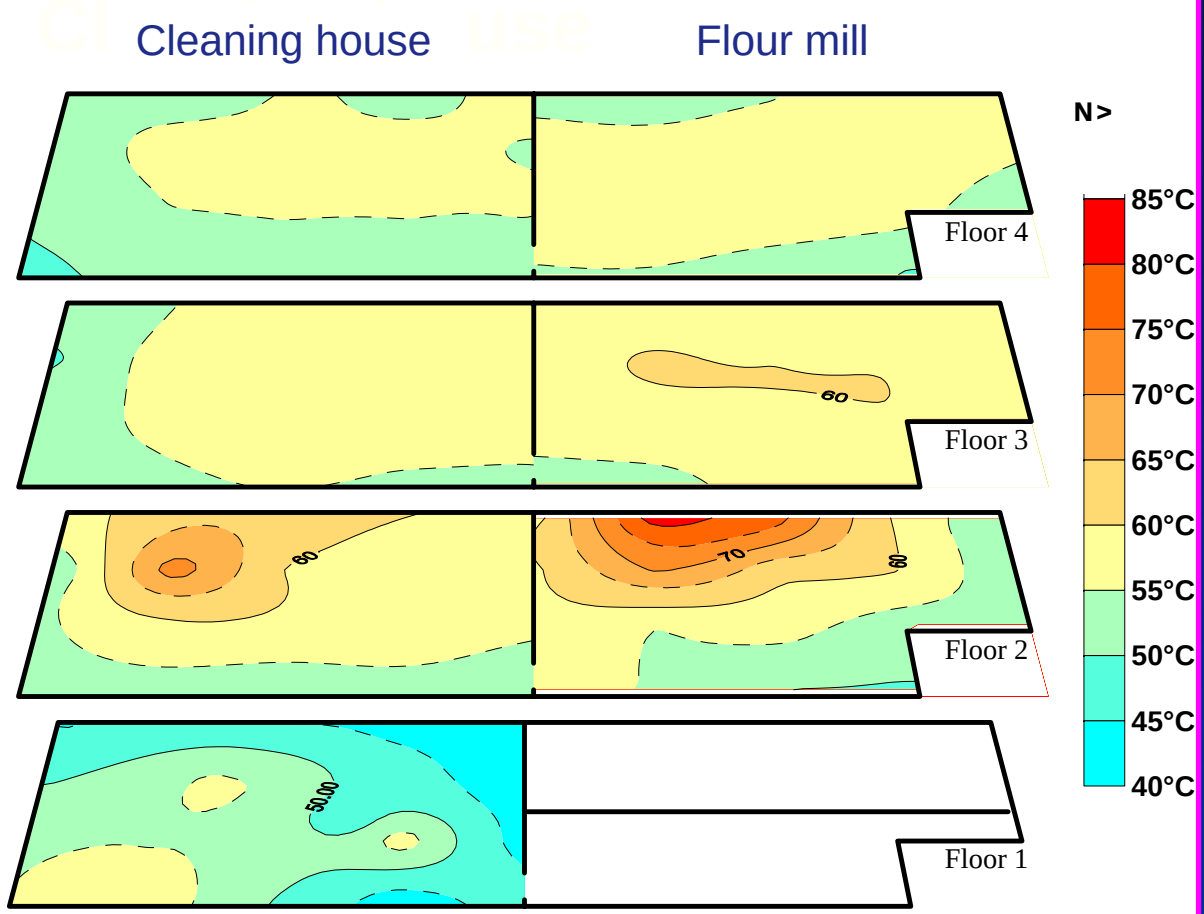
A novel method for analyzing grain facility heat treatment data

~ Maximum temperature distributions ~



Flour mill 1 was not studied.

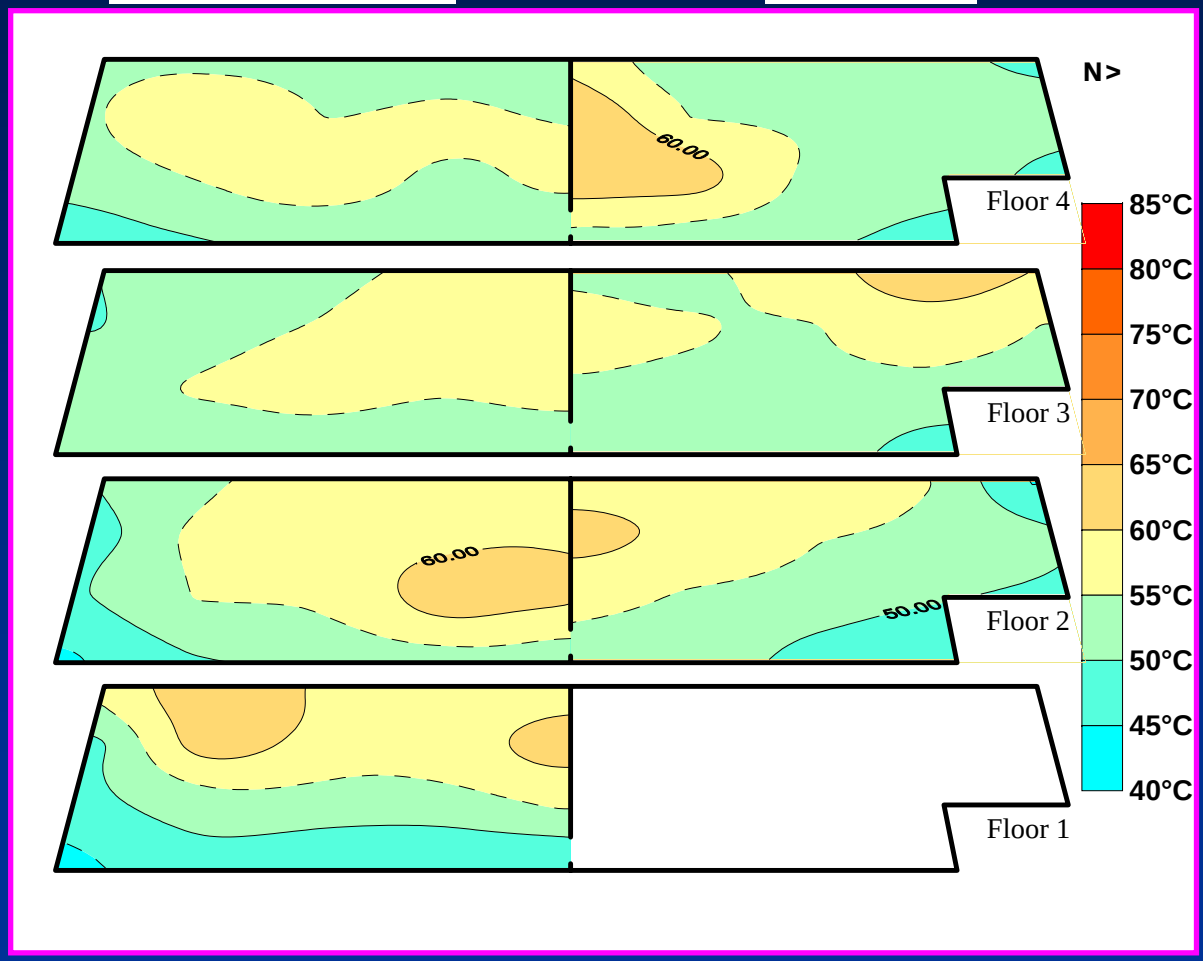
Gas heating


Cleaning house
Flour mill
N>
85°C
80°C
75°C
70°C
65°C
60°C
55°C
50°C
45°C
40°C
Floor 4
Floor 3
Floor 2
Floor 1
60
60
70
60
50.00

Electric heating

Cleaning house

Flour mill



A novel method for analyzing grain facility heat treatment data
~ Main points ~

- Heat treatment as an alternative to chemical treatments
- Different heating patterns of gas and electric heating-Time delays; % A under/over-heated
- Sufficient heat treatment & uniform heat distribution
- Quantification & identification of over-heated & under-heated areas
- Characterizing the heating pattern of each method via modeling (log-logistic eqn.)

Thank you

The End