

Time Temperature Indicators (TTIs) a Historical Perspective, Current Applications and Usage

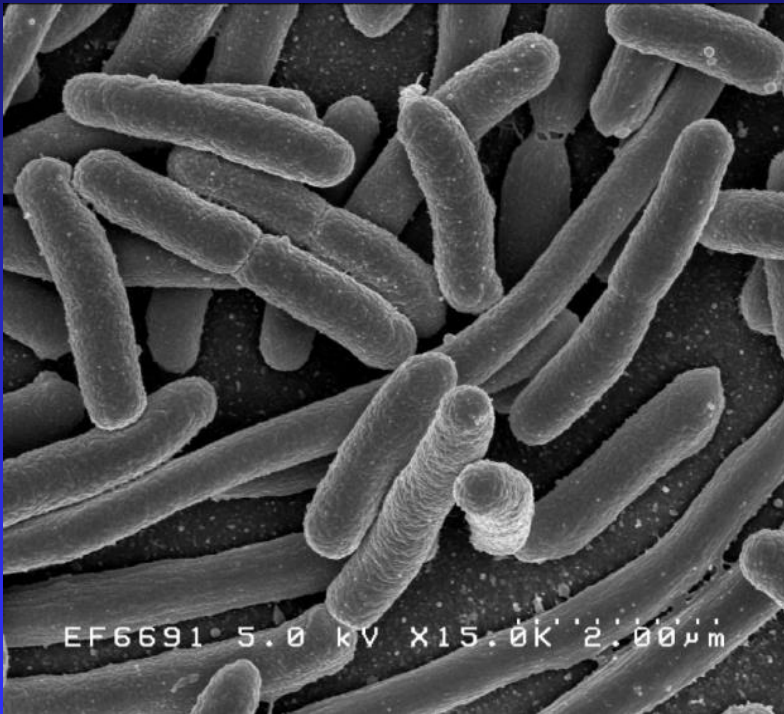
Peter Rönnow Ph.D.
Vitsab International AB

From Producer to Consumer

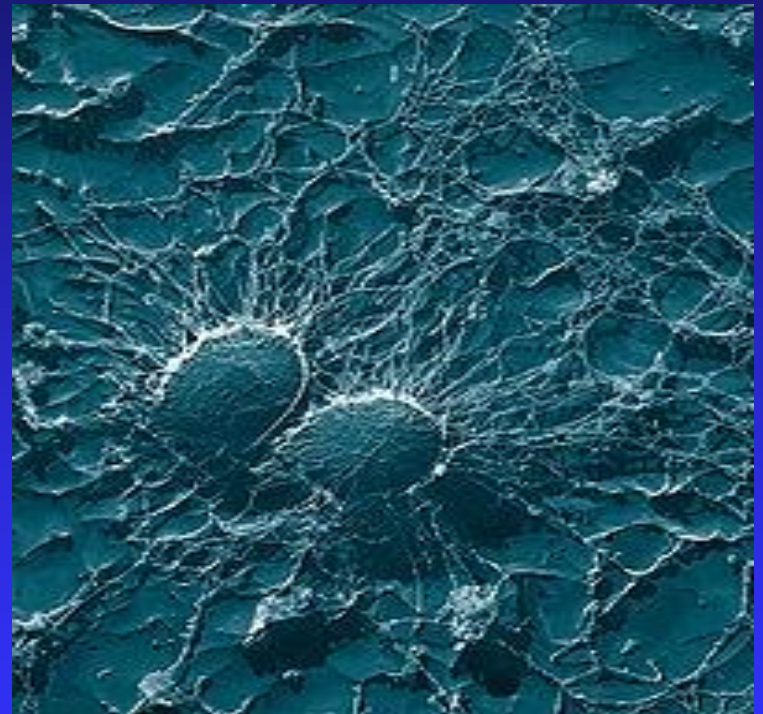


All Foods are Associated with Bacteria

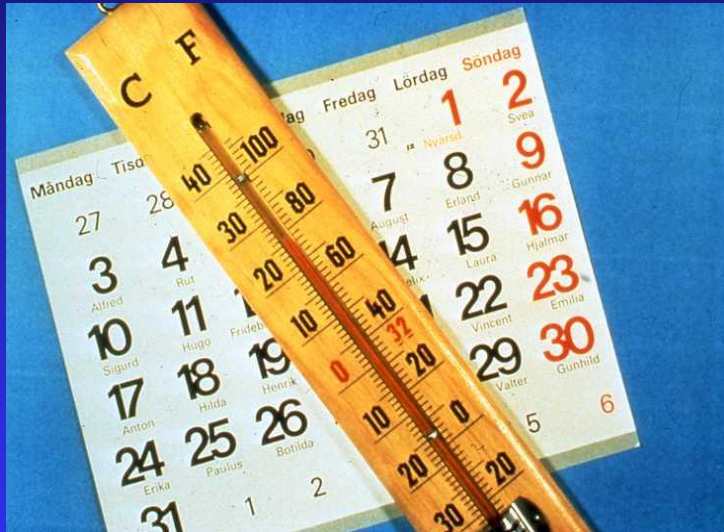
Escherichia coli



Staphylococcus aureus



Need for monitoring of time and temperature of food transports



Temperature control during storage and distribution



Temperature recorders and loggers need evaluation of temperature profile

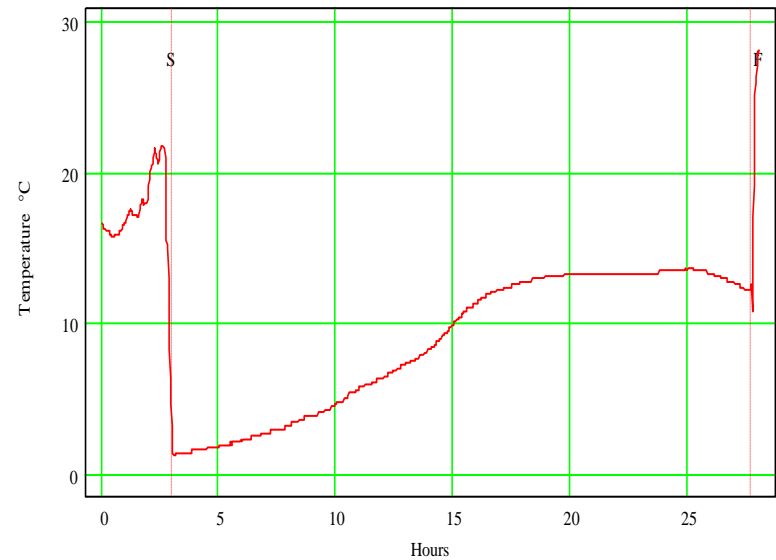


Fig. 6 Logged temperature profile of air shipment

Temperature indicating label types

Types		Indication
CTI	Critical Temperature indicators	Temperature above a set temperature
CTTI	Critical Time-Temperature Integrators	Temp. Integration start above a set temperature
TTI	Full History Time-Temperature Integrators	Temp. Integration starts at activation

Full history TTIs

TTI Producer	Reaction type	Colour signal	Ea range
LifeLine™	Chemical polymerization	Darkening of centre of bulls eye window	84 – 100 kJ/mol
3M Monitor Mark®	Physical diffusion of chemical solute	Coloured front migrating on white wick	32 – 50 kJ/mol
VITSAB TTI	Biochemical Enzymatic hydrolysis of lipid	Colour change in window from green to yellow or red	50 – 210 kJ/mol

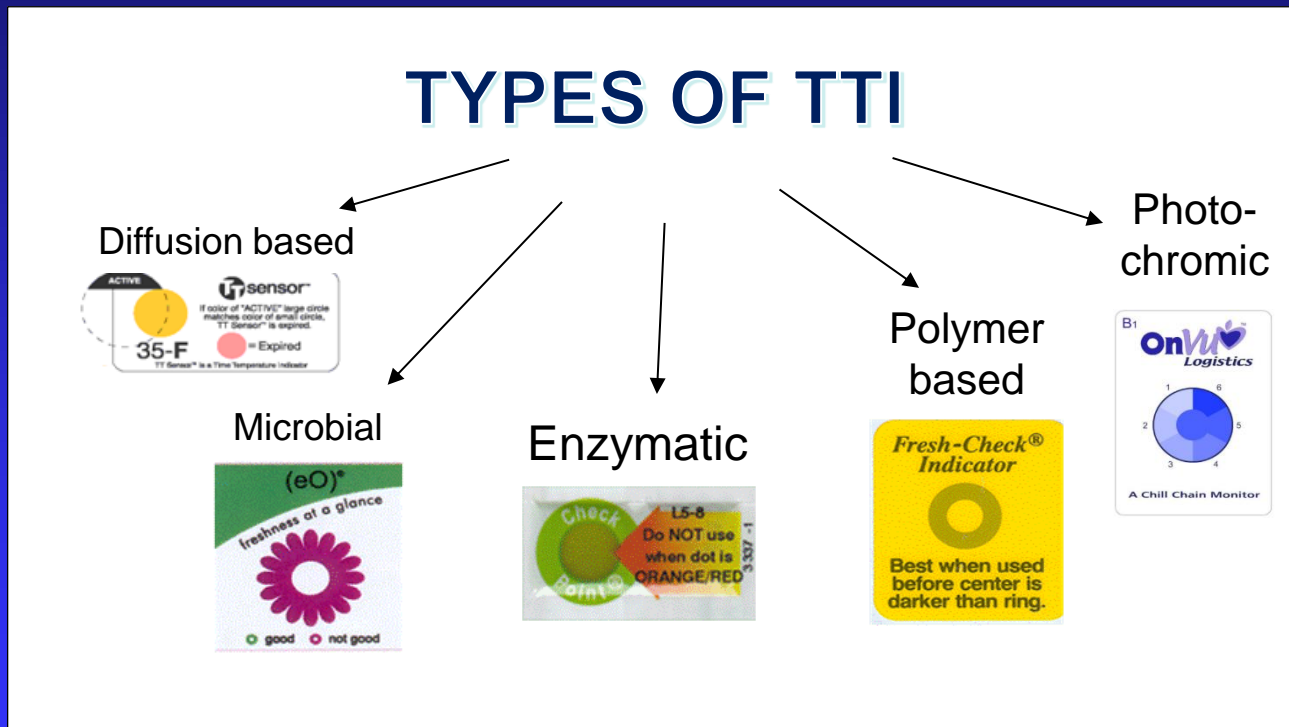
An *ideal TTI* should have the following properties:

- Respond only to time-temperature changes.
- The response should be irreversible and easy to measure.
- Correlation to quality changes in the food or beverage or to shelf life changes.
- Reliable with consistent response to same temperature conditions.
- Low cost.
- Be small and easy to integrate as part of food package and compatible with high speed packaging process.
- Have a long shelf life before activation and easy to activate.
- Resistant to normal mechanical abuses and response cannot be tampered.
- Nontoxic due to its close proximity to food product.
- Easy to read by human eye by personnel or consumers .

From:

Taoukis P.S. and Labuza T.P. 2003. Time-Temperature Indicators (TTI). In: *Novel Food Packaging Techniques*. R. Ahvenainen , ed. Woodhead Publishing Limited, Cambridge, UK and CRC Press LLC, Boca Raton FL, USA, 2003; 103-126.

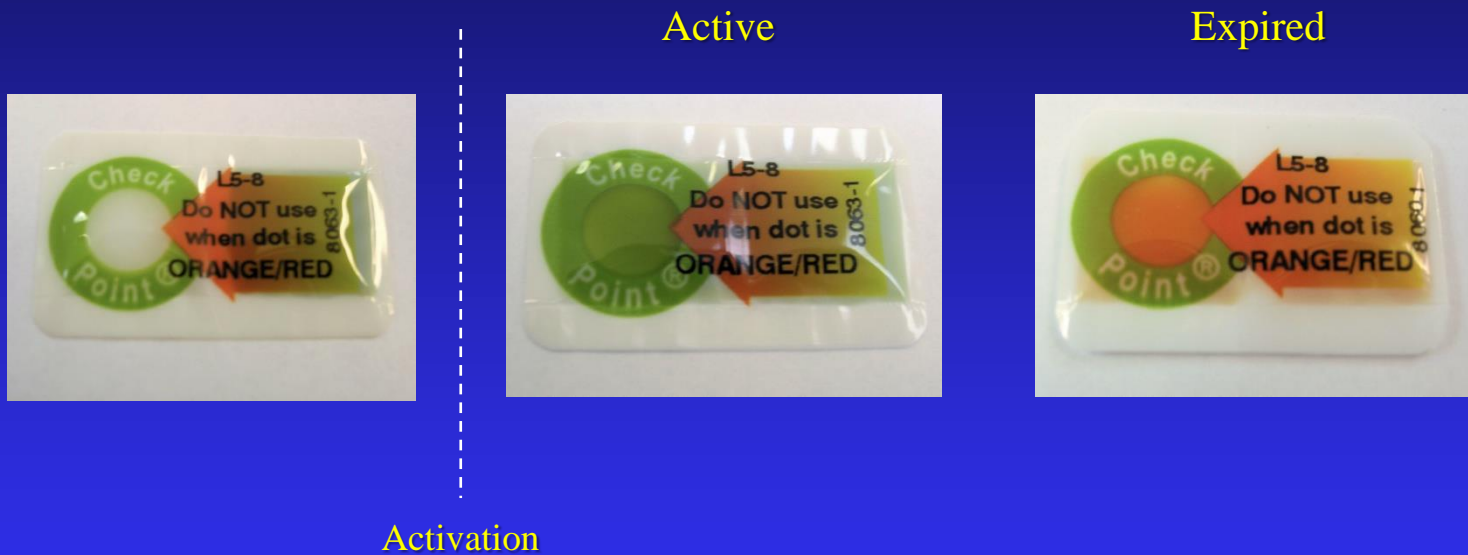
Time Temperature Integrators (TTIs) are simple, inexpensive devices that can show an easily measurable, time and temperature dependent change that cumulatively indicates the time-temperature history of the product from the point of manufacture to the consumer, allowing the location and the improvement of the critical points of the chill chain



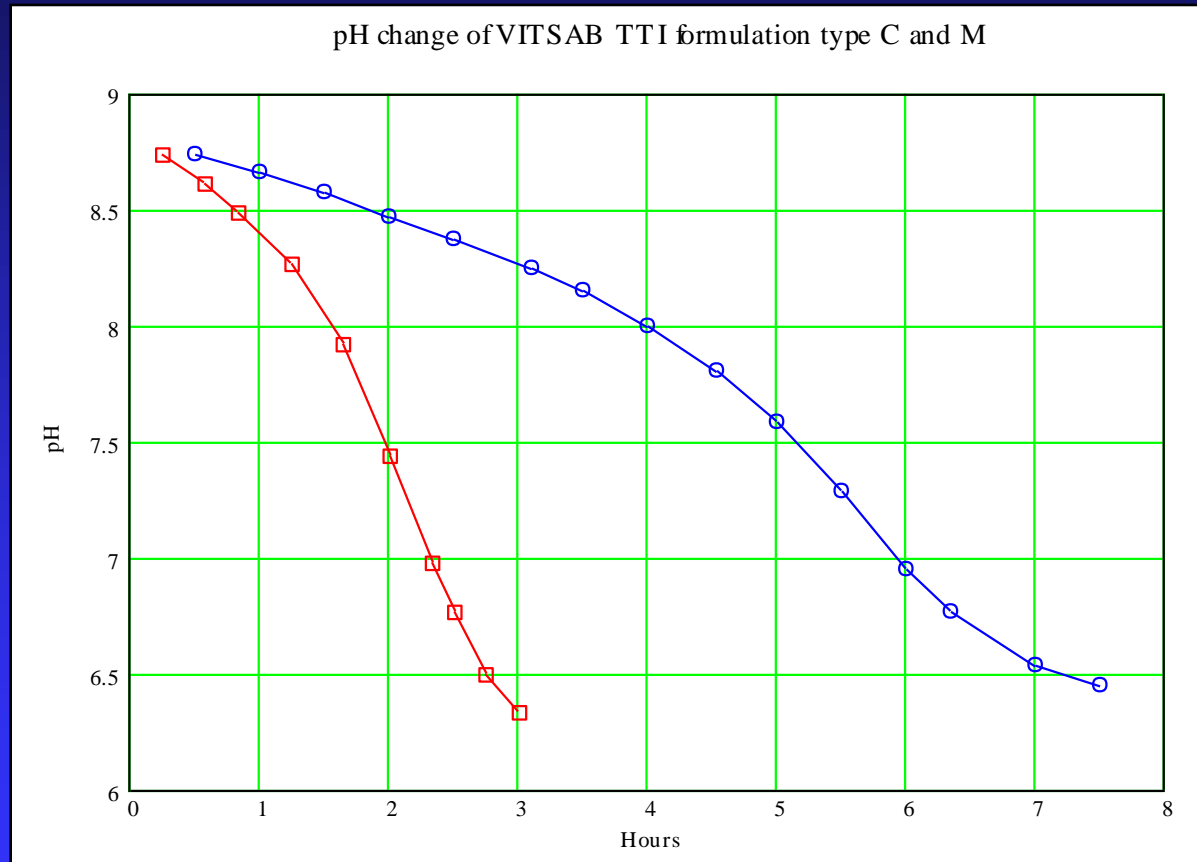
Basic principles of a TTI function

- Physical reaction
 - Diffusion in supporting material
- Chemical reaction
 - Polymer reaction
 - Biochemical enzyme reaction

Vitsab TTI or Smart Label

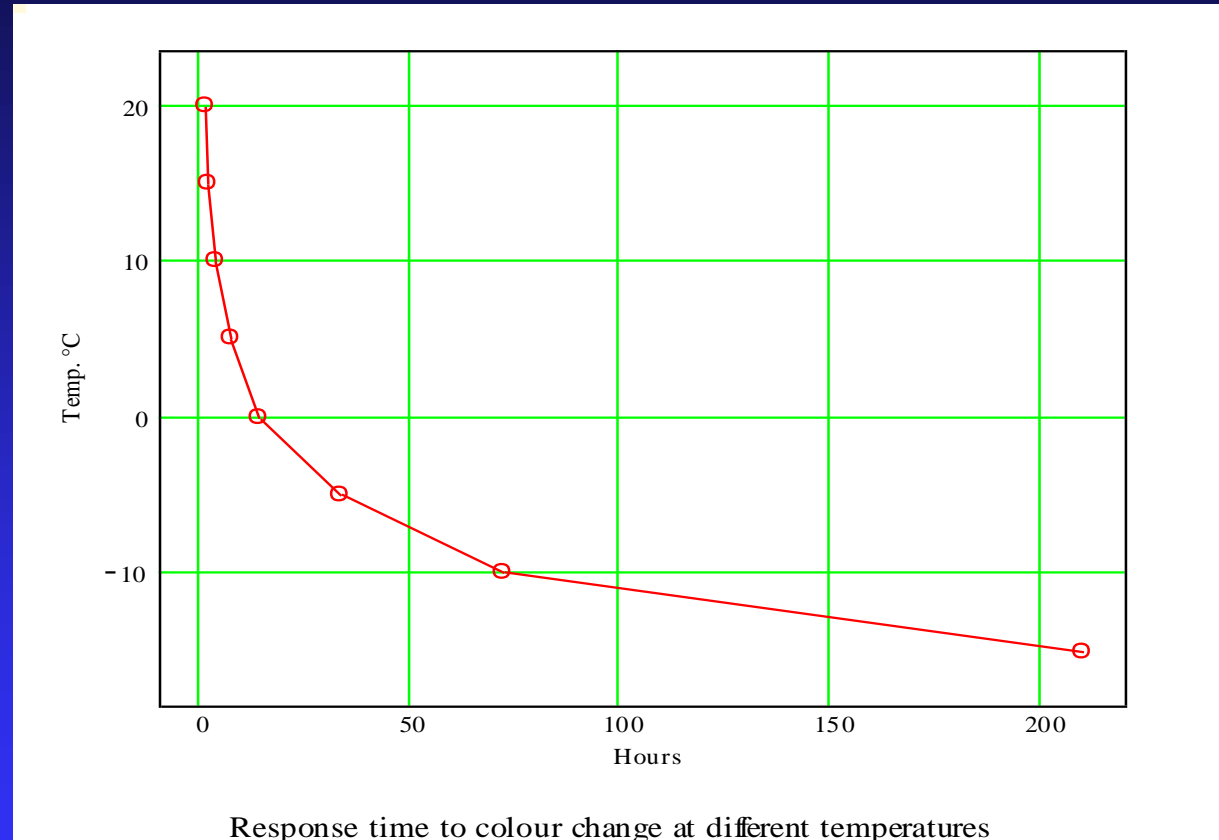


pH change due to fatty acid release from lipase activity



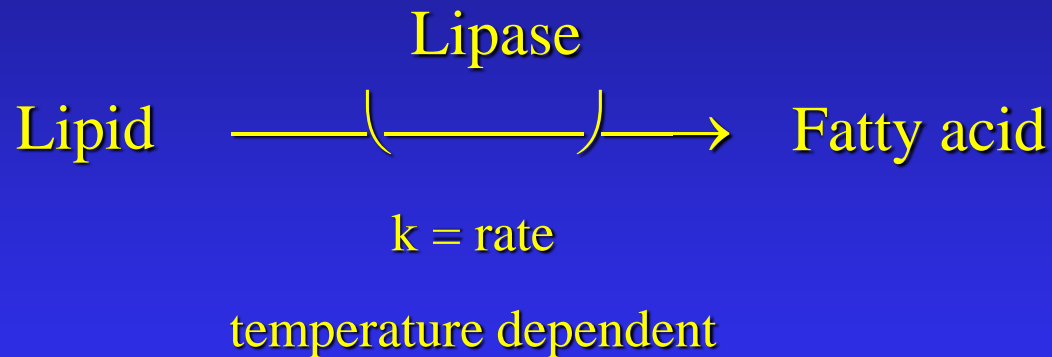
Response times of TTI labels at different constant temperatures

Temp °C	Response time hours
20	1
15	2
10	3.5
5	7.2
0	14
-5	33
-10	72
-15	210



VITSAB[®] Time-Temperature Indicators

Use an enzyme reaction



Arrhenius equation

$$k = A \cdot e^{-\frac{Ea}{R \cdot T}}$$
$$\ln k = \ln A - \frac{Ea}{R} \cdot \frac{1}{T}$$

k = rate of reaction

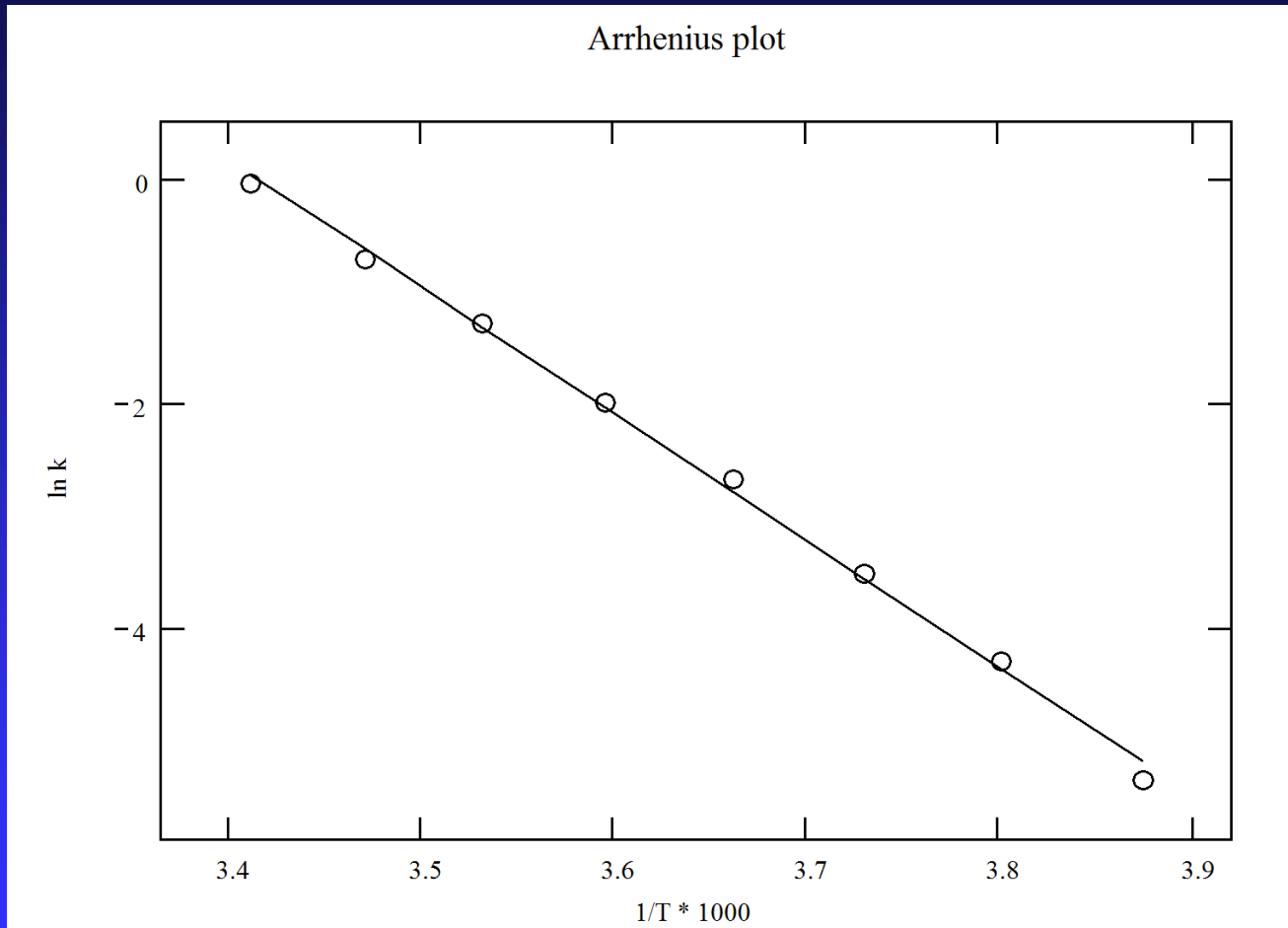
A = constant of the equation

R = universal gas constant

T = absolute temperature °K

Ea = Arrhenius energy of activation

Arrhenius plot of experimental data



British Airways requirements and food regulations for catered food

All meals from kitchen consumed within 24 hours

Exposure to temperatures above 10 °C max 4 hours

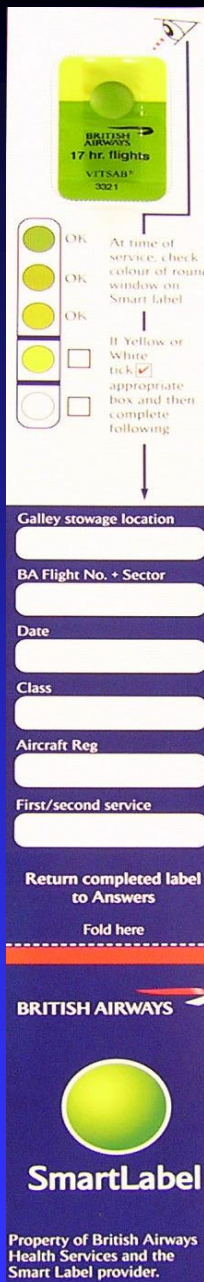
Bacterial growth is the general concern behind health and food regulations

Low temperatures such as 2 – 8 °C
give no or slow growth of bacteria

Shelf life (safe to eat) below 8 °C 2 – 3 days

Predictive challenge test using Food Micro model developed by Leatherhead Food Research Association

Hours to reach a 1000 fold increase of bacterial counts cfu/g				
° C	Staph. aureus	Listeria monocytogenes	Bacillus cereus	Flight Label run time (hours)
22	8	18	18	3.2
15	22	72	96	8.0
10	72	156	144	15.8



BRITISH AIRWAYS
17 hr. flights
VITSAB®
3321

At time of service, check colour of round window on Smart label

If Yellow or White tick appropriate box and then complete following

Galley stowage location

BA Flight No. + Sector

Date

Class

Aircraft Reg

First/second service

Return completed label to Answers

Fold here

BRITISH AIRWAYS

SmartLabel

Property of British Airways Health Services and the Smart Label provider.

Vitsab® Flight Label

Smart Label concept for monitoring catered meals on board BA flights



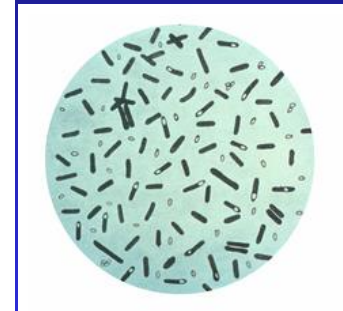
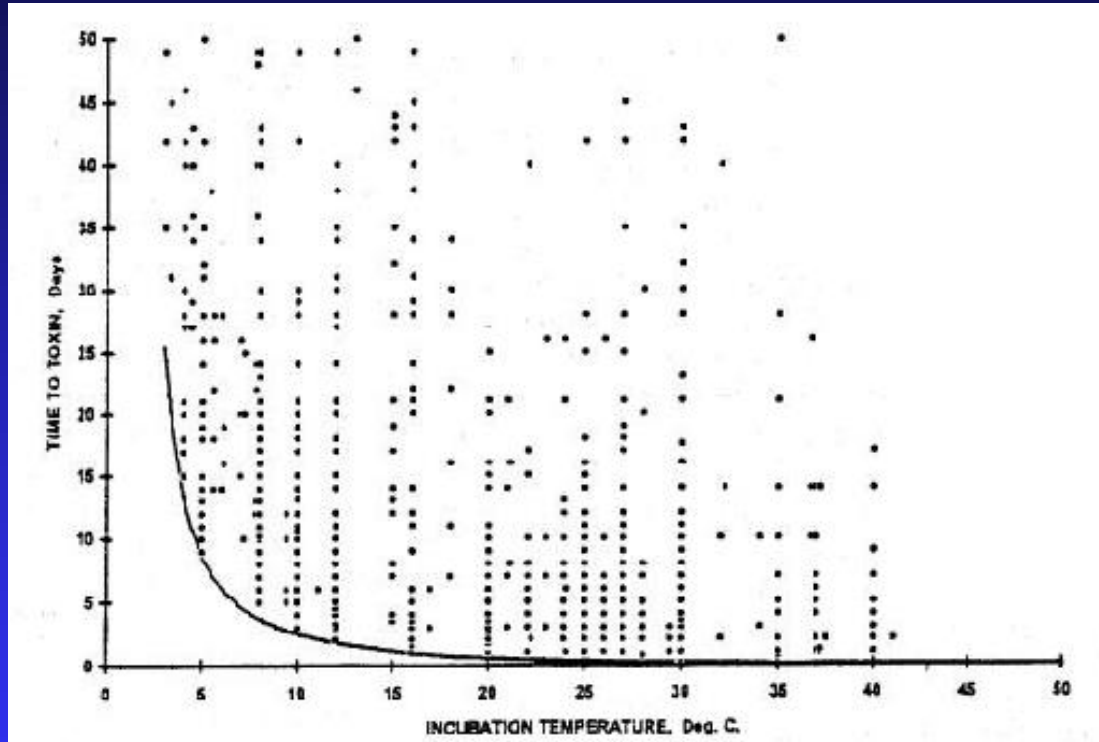
Flight Label in trolley onboard aircraft



FDA Import Alert 16-125 of packed fresh seafood to USA

Requiring HACCP program with special attention
towards temperature monitoring and control
throughout the shipment

Time and temperatures conditions for toxin formation of *Clostridium botulinum*



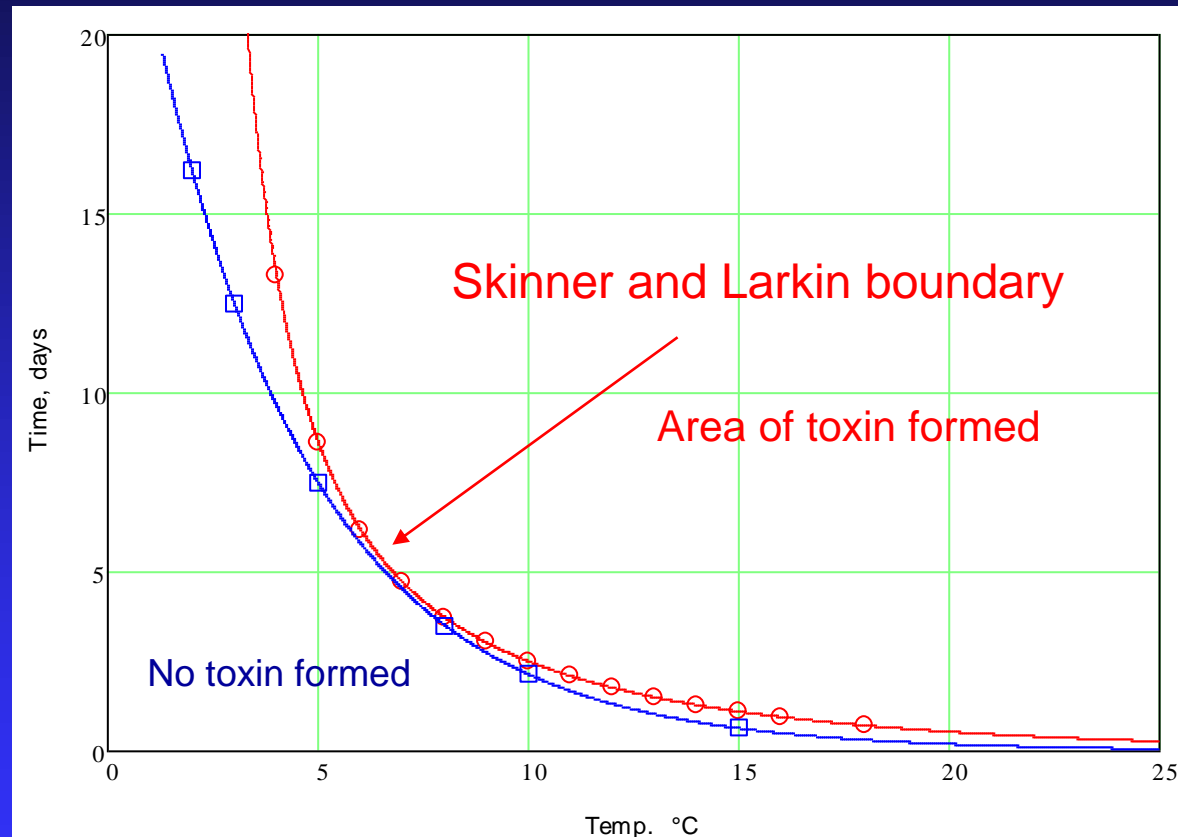
Journal of Food Protection, Vol. 61, No. 9, 1998, Pages 1154-1160
Copyright ©, International Association of Milk, Food and Environmental Sanitarians

Conservative Prediction of Time to *Clostridium botulinum* Toxin Formation for Use with Time-Temperature Indicators To Ensure the Safety of Foods

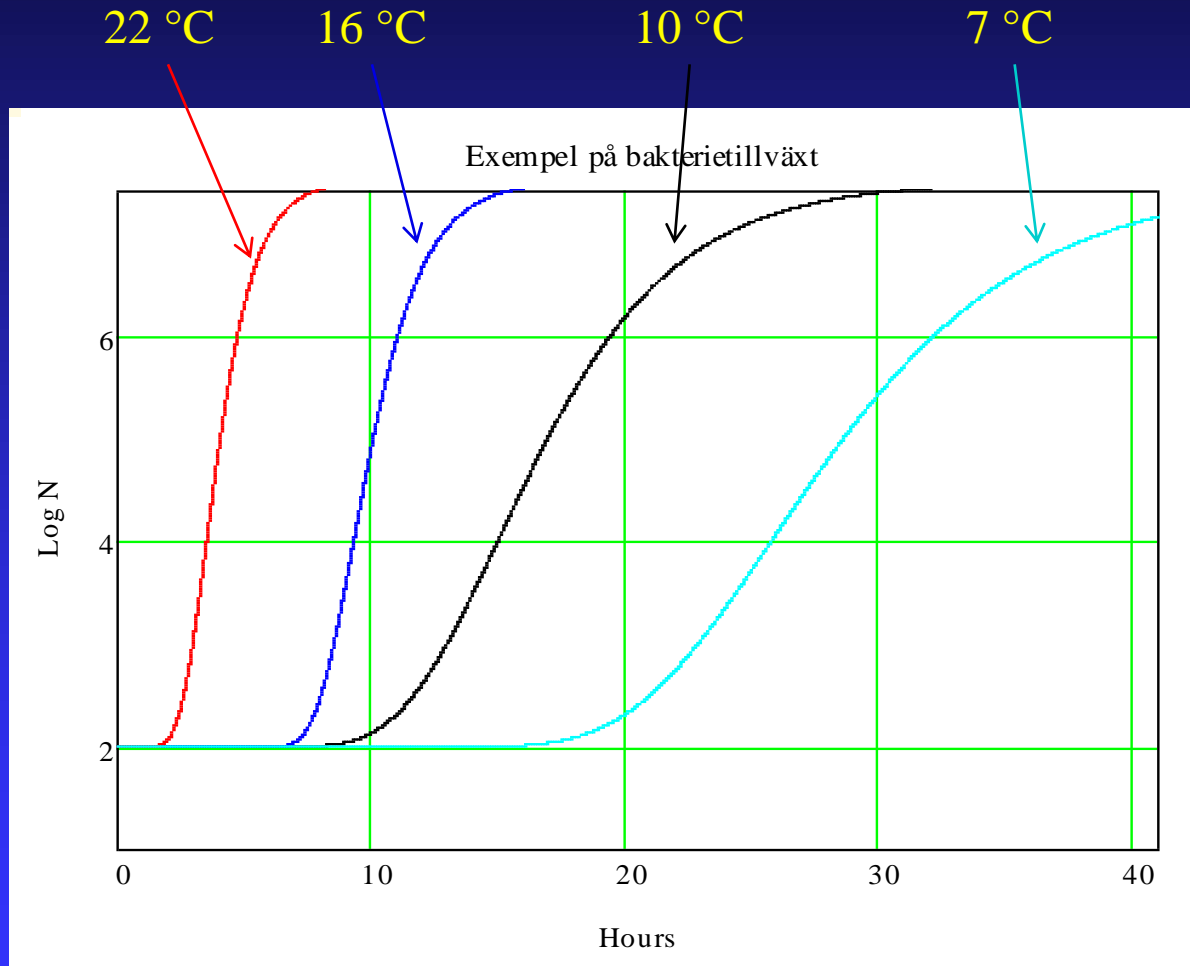
GUY E. SKINNER* AND JOHN W. LARKIN

$$\log(LT) = 0.65 - 0.0525 \cdot t + 2.74 \cdot \frac{1}{t}$$

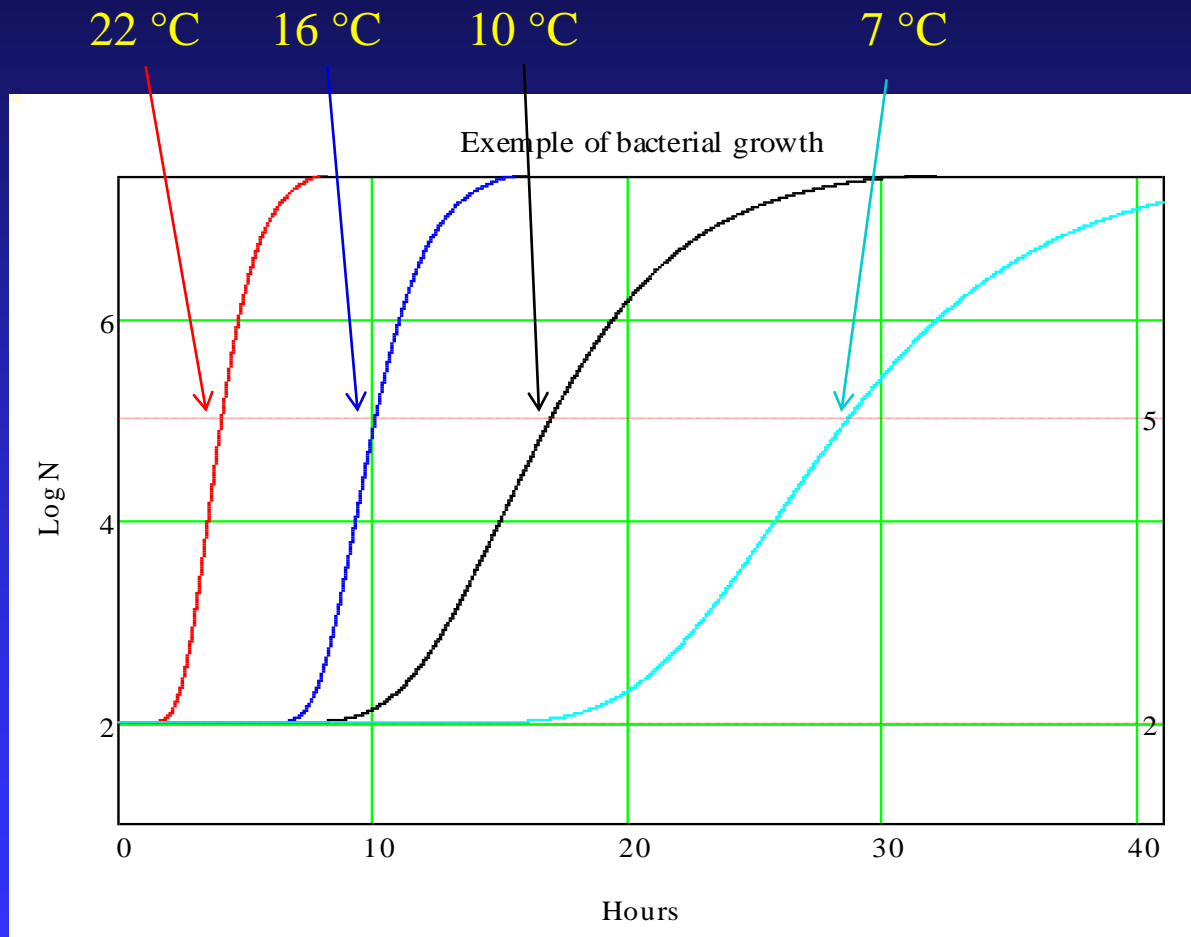
Adaptation of Vitsab TTI-formulation to *Clostridium botulinum* toxin formation



Growth of bacteria at different temperatures



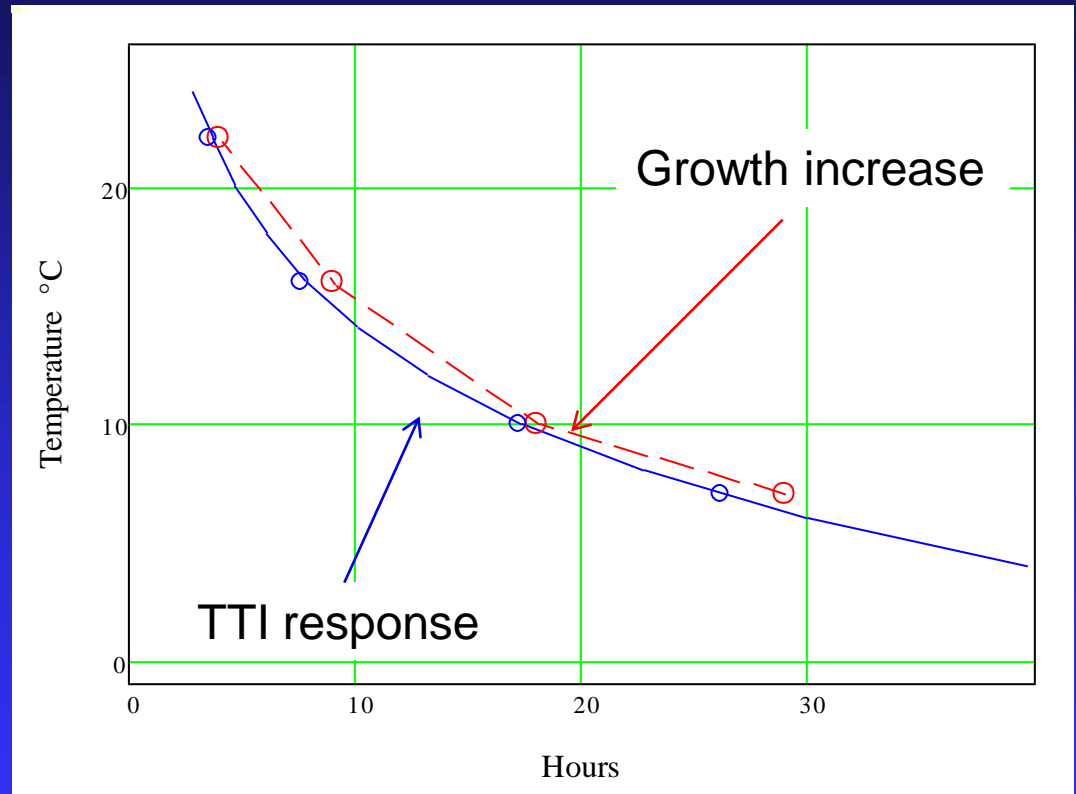
Growth of bacteria to a 1000 fold increase



Temp °C	Time to 1000 fold increase of bacteria
7	29
10	18
16	9
22	4

Adaptation of TTI indicator to an application

Temp °C	Hours	
	TTI response time	Growth increase
7	26.1	29
10	17.2	18
16	7.2	9
22	3.5	4



Oyster harvest practice



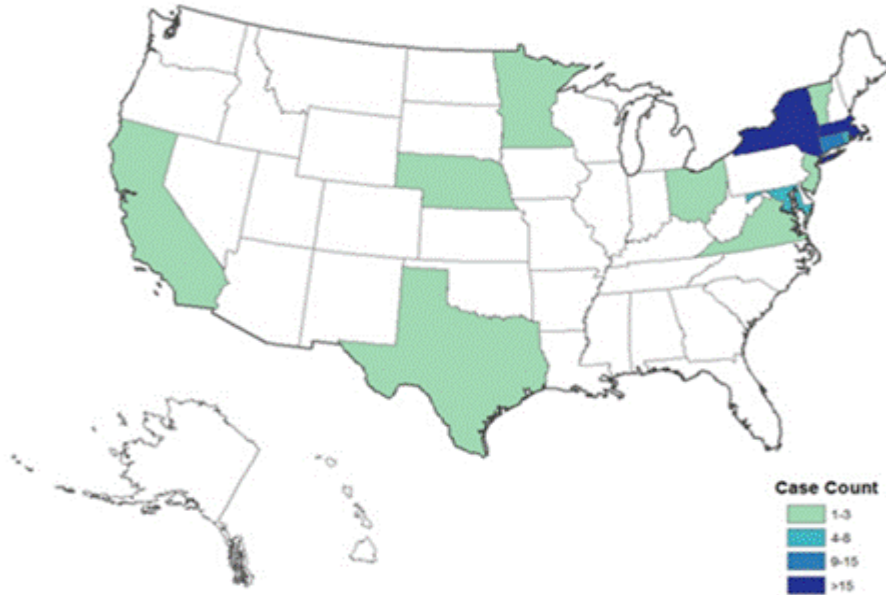
Vitsab Int. *Vibrio* spp. infection associated with consumption of shellfish

Increase in *Vibrio parahaemolyticus* illnesses associated with consumption of shellfish from several Atlantic coast harvest areas, United States, 2013

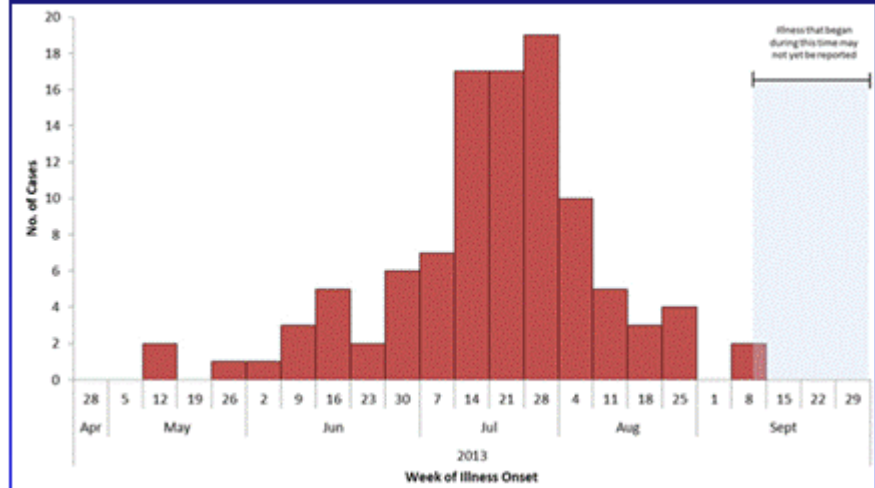
Posted October 21, 2013 11:45 AM ET

Case Count Map

Persons infected with the outbreak strain of *Vibrio parahaemolyticus*, by State*



Centers for Disease Control and Prevention
CDC 24/7: Saving Lives. Protecting People.™



Ongoing warm weather increases risk of illness associated with raw shellfish consumption

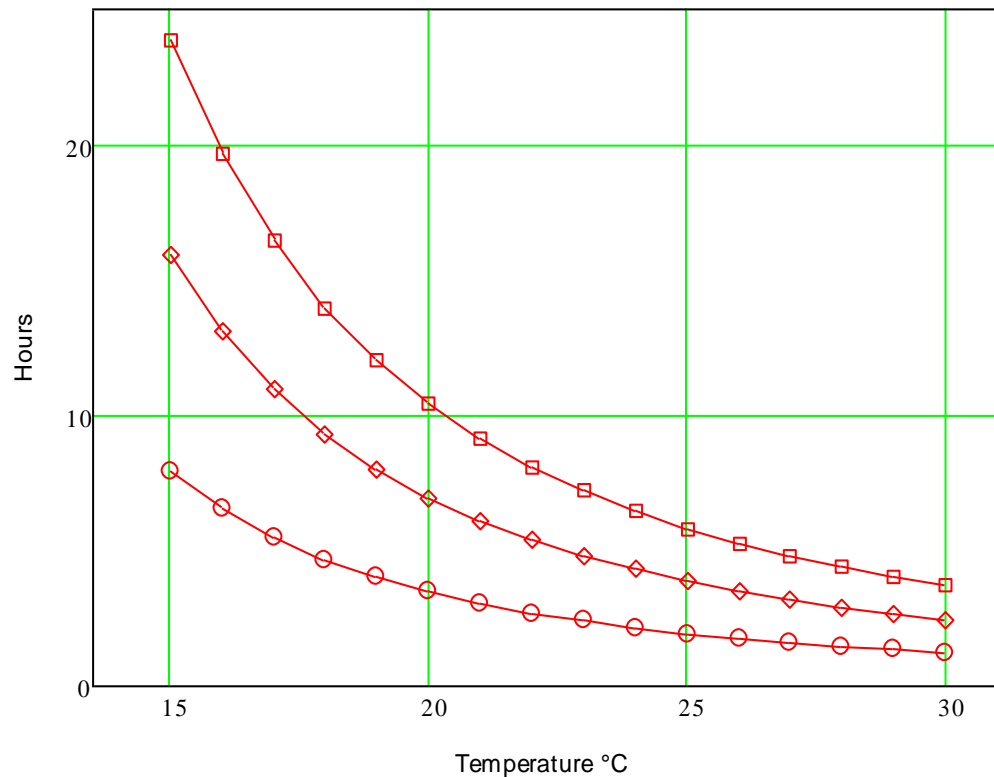
July 31, 2015

Vancouver – An unprecedented number of shellfish-related illnesses have occurred this summer, with 35 cases of *Vibrio parahaemolyticus* infections reported to the BC Centre for Disease Control (BCCDC) in June and July.

Growth of *Vibrio parahaemolyticus*, Doubling times at 15 – 30°C temperature range

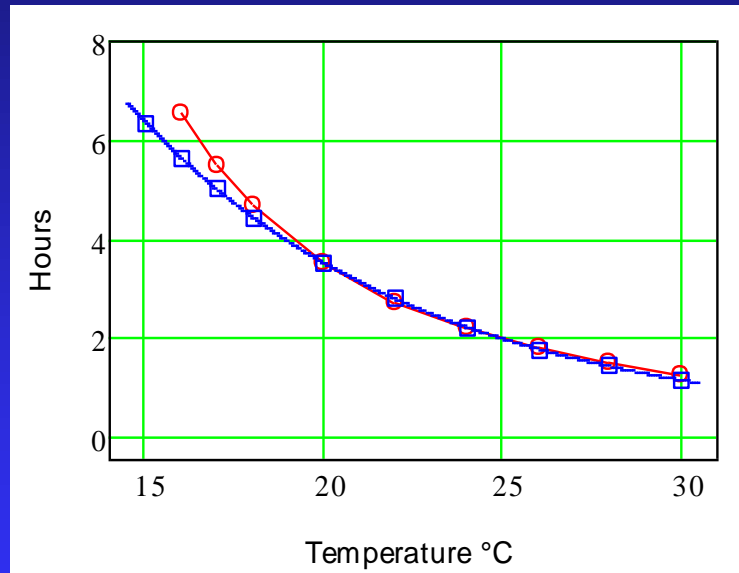
Data from John Bowers, U.S. FDA

Vibrio parahaemolyticus growth			
Temp. °C	Time to doublings, hours		
	one	two	three
15	7.95	15.9	23.85
16	6.54	13.09	19.63
17	5.48	10.96	16.44
18	4.65	9.31	13.96
19	4	8.01	12.01
20	3.48	6.96	10.44
21	3.05	6.11	9.16
22	2.7	5.4	8.1
23	2.4	4.81	7.21
24	2.16	4.31	6.47
25	1.94	3.89	5.83
26	1.76	3.52	5.28
27	1.6	3.21	4.81
28	1.47	2.93	4.4
29	1.34	2.69	4.03
30	1.24	2.48	3.71

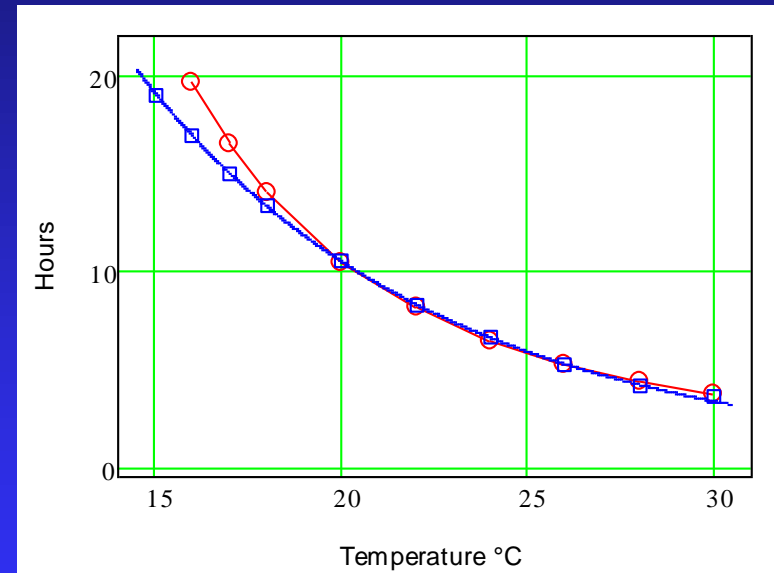


TTI-Label adapted to *Vibrio parahaemolyticus* growth

Time to one doubling

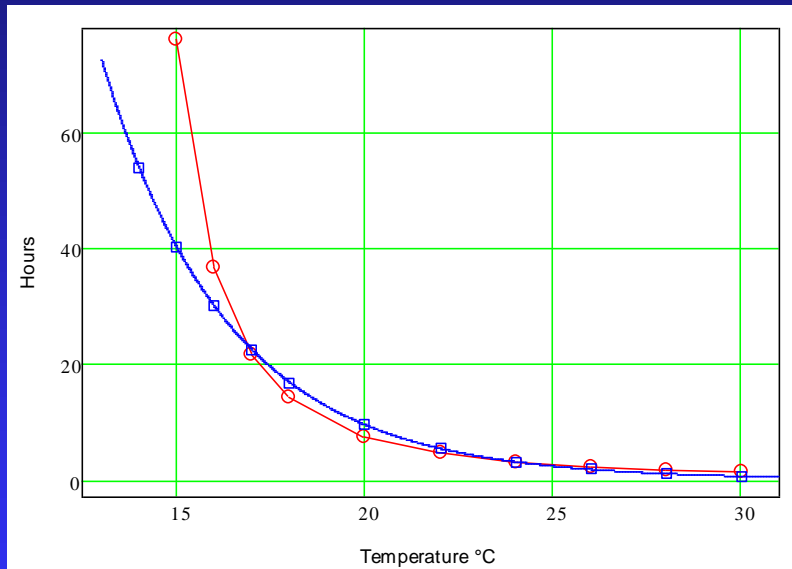


Time to three doublings

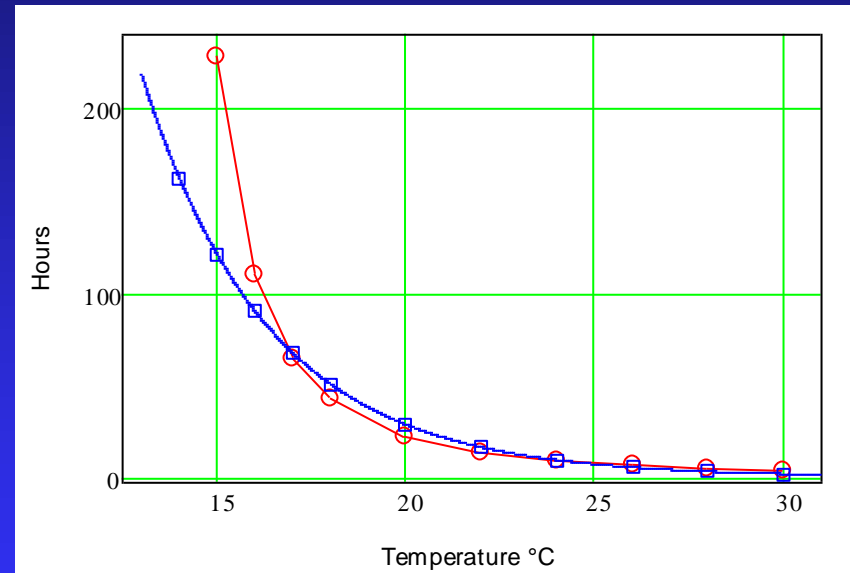


TTI-Label adapted to *Vibrio vulnificus* growth

Time to one doubling



Time to three doublings








Monitoring oyster temperature after harvest



Oysters safe to eat



Current Vitsab TTI applications

Application	TTI indication	Users	Reason for use
	Risk for food poisoning	British Airways, SAS and Aer Lingus	UK health authority regulation
	Risk for <i>Clostridium botulinum</i> toxin formation	Seafood producers in USA and from other parts of the world with export to USA	U.S. FDA requirements
	Risk for growth of <i>Vibrio parahaemolyticus</i> or <i>Vibrio vulnificus</i> in oysters after harvest	Oyster producers in USA	U.S. FDA requirements
	Food quality	Airline kitchen in Abu Dhabi	Food quality validation
	Freshness indication	LSG Sky Chefs serving Lufthansa flights	Food quality validation

TTI Usage in monitoring food products

Prof of concept evidenced by Food Science Research
since more than 40 years

- Shelf Life adaptations e.g. – Use by date, Best before dating or Food spoilage
- Quality changes in food products: Fresh, Chilled and Frozen
- Risk assessments of e.g. Catered food for Airlines and Toxin formation by *Clostridium botulinum* toxin
- Bacterial growth prediction: Risk of food spoilage and growth risk of pathogenic bacteria e.g. *Vibrio parahaemolyticus* and *Vibrio vulnificus* in oysters.

VITSAB[®] International AB

Dr. Peter Ronnow

Thank you