

APEC High Level Public-Private Forum on Cold Chains
to Strengthen Agriculture and Food's Global Value Chain
(ATC 01 2014A)

Hotel Shiroyama Kagoshima, Kagoshima Prefecture
28 October, 2015

Recent Development in the Cold Chain System in Japan - Toward the Food Value Chain -

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Outline

- Introduction
- Effects of Environmental Conditions on the Quality of Fresh Fruits and Vegetables
- Recent Development in the Cold Chain in Japan
- Toward the Food Value Chain based on the Quality Assurance System
- For Sustainable Food Supply Chain

Changes of Food Consumption and PFC Balance in Japan



1965, release of the Cold Chain Counsel
 *Self Sufficient Rate

<http://www.maff.go.jp/>

Goal : 13%P, 27%F, 60%C

Life style related diseases are increasing

Major Causes of Death and ratios in Japan (being updated)

	Ratio (%)			
	1980	1998	2004	2013
Tuberculosis	0.9	0.3	0.2	0.2
Cancer	22.4	30.3	31.1	28.8
Diabetes	1.2	1.3	1.2	1.1
Heart Diseases	17.1	15.3	15.5	15.5
High Blood Pressure	2.2	0.7	0.6	0.6
Cerebral Vessel	22.5	14.7	12.5	9.3
Pneumonia	4.6	8.5	9.3	9.7
Asthma	0.9	0.5	0.3	0.1
Ulcer	0.8	0.4	0.3	0.2
Lung	2.6	1.7	1.5	1.3
Renal Insufficiency	1.0	1.8	1.9	2.0
Decrepitude	4.4	2.3	2.3	5.5
Accident	4.0	4.2	3.7	3.1
Traffic	1.8	1.4	1.0	0.5
Suicide	2.8	3.4	2.9	2.1

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Goal : 13%P, 27%F, 60%C

Mineral and Vitamin Supply from Fruits and Vegetables in Japan

(National Nutrition Survey, 2011)

Food stuff	Intake kcal	Minerals		Vitamins				
		Ca mg	Fe mg	A μgRE	B1 mg	B2 mg	Folic Acid μg	C mg
Total	1840.0	507.0	7.5	532.0	1.49	1.46	281.0	110.0
Animal	441.0	211.0	2.1	176.0	0.36	0.57	34.0	6.0
Plant	1399.0	297.0	5.4	355.0	1.13	0.89	247.0	104.0
Grains	773.0	43.0	0.9	3.0	0.17	0.11	27.0	8.0
Fruits(A)	63.0	10.0	0.2	29.0	0.05	0.02	18.0	32.0
<i>Ratio of fruits (%)</i>	<i>3.4</i>	<i>2.0</i>	<i>2.7</i>	<i>5.5</i>	<i>3.4</i>	<i>1.4</i>	<i>6.4</i>	<i>29.1</i>
Potatoes (B)	39.0	10.0	0.2	0.0	0.03	0.01	10.0	8.0
Vegetables (C)	67.0	89.0	1.1	291.0	0.10	0.09	106.0	34.0
<i>Ratio of C (%)</i>	<i>3.6</i>	<i>17.6</i>	<i>14.7</i>	<i>54.7</i>	<i>6.7</i>	<i>6.2</i>	<i>37.7</i>	<i>30.9</i>
Green	25.0	39.0	0.5	250.0	0.04	0.05	46.0	16.0
Others	34.0	40.0	0.4	8.0	0.04	0.03	54.0	16.0
Mushroom (D)	3.0	0.0	0.1	0.0	0.02	0.02	4.0	0.0
<i>Ratio of A+B+C+D (%)</i>	<i>9.3</i>	<i>21.5</i>	<i>21.3</i>	<i>60.2</i>	<i>13.4</i>	<i>9.6</i>	<i>49.1</i>	<i>67.3</i>
National Nutrition Survey in Japan by Ministry of Health and Welfare, 2011								
Potatoes include potato and sweet potato.								

食事 バランスガイド

1 日 分

料理例

5-7 Staple 2次題

Staple 2 (難)

Vegetative

Meat&Fish

Milk&products

Fruits

1つ分 =  =  =  = 
二握分の盛り1杯 = 西に握り1握 = 食パン1枚 = ロールパン2個

1.5杯分 =  2つ分 =  =  = 
二握分の盛り1杯 = 西に握り1握 = 食パン1枚 = ロールパン2個

つゆ =  軽福りら  恋ゆかりと白のあめ
のち焼  真にくん
真様で  まつれん果の
お返し  ひん香の贈物  真田  恋のこソナー

【つゆ】 =       

1つ分 =  =  =  =  =  =  =  =  = 

2つ分 =  =  =  =  =  =  =  = =

3つ分 =  =  =  =  =  =  =  =  = 

1/2カップ分 =  =  =  =  =  =  =  =  = 

1/3カップ分 =  =  =  =  =  =  =  =  = 

1/4カップ分 =  =  =  =  =  =  =  =  = 

1/5カップ分 =  =  =  =  =  =  =  =  = 

1/6カップ分 =  =  =  =  =  =  =  =  = 

1/8カップ分 =  =  =  =  =  =  =  =  = 

1/10カップ分 =  =  =  =  =  =  =  =  = 

1/12カップ分 =  =  =  =  =  =  =  =  = 

1/15カップ分 =  =  =  =  =  =  =  =  = 

1/20カップ分 =  =  =  =  =  =  =  =  = 

1/25カップ分 =  =  =  =  =  =  =  =  = 

1/30カップ分 =  =  =  =  =  =  =

1つ分 = みるく1箱、りんご1個、おむすび1個、おせんべい1袋、ぶどう1房、いちご1個

※SVとはサービング(食事の提供量の単位)の略

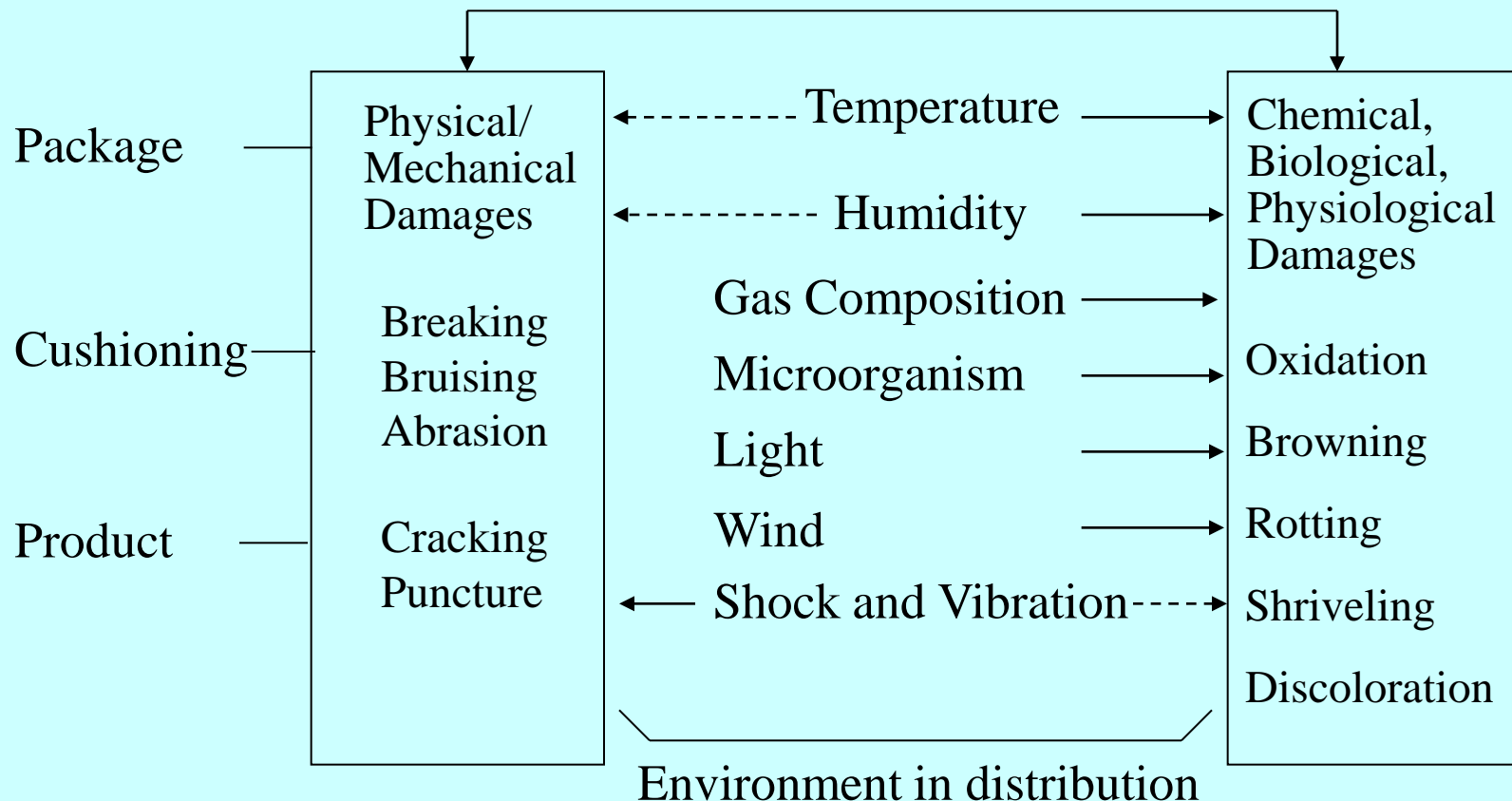
by Ministry of Agriculture, Forestry and Fisheries (MAFF)
and Ministry of Health, Labour and Welfare (MHLW)
in June 2005

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Effects of the Environmental Conditions on the Food Quality

Interaction appears in biological materials



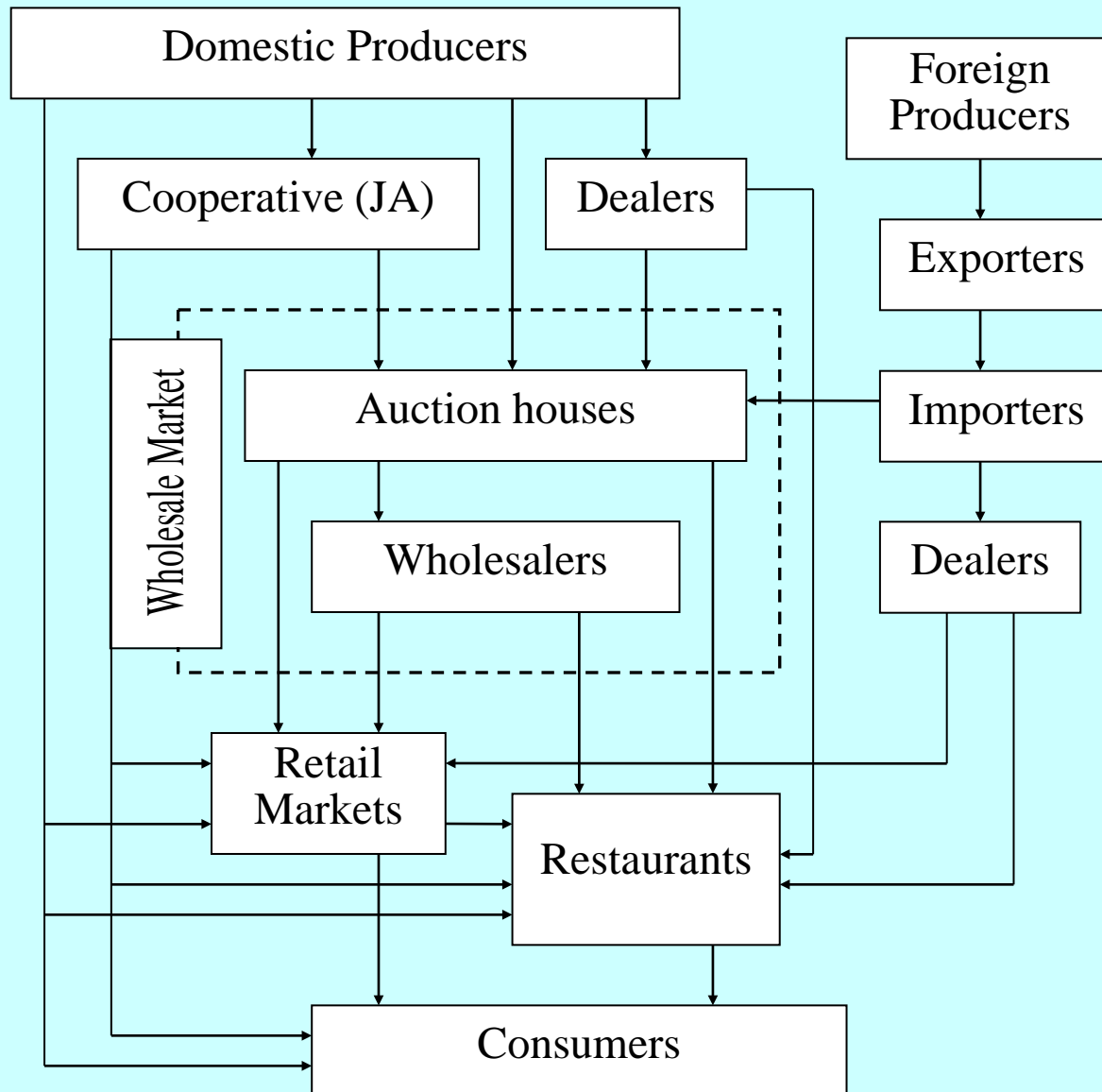
Characteristics of Fruits and Vegetables

- Living→respire, transpire
- Stress by harvest→damage, cut of source
- High water content→desiccation
- Part of plant: leaf, stalk, fruit, bud, root, flower
- Many kinds: different characteristics
- Non-Uniform: variety, growing condition, stage

Fundamentals of preserving Fruits and vegetables

- **Avoid damage**→reduce shock and vibration during handling and transportation
- **Keep low temp.**→precooling, cold storage, heat insulation, coolant
- **Keep high humidity**→humidifier, packaging, coating
- **Low O₂ and/or high CO₂**→CA, MA
- **Low ethylene**→ethylene absorbent
- **Microbial control**→sanitation, low temp., disinfectant

Distribution Channels of Fresh Produce in Japan



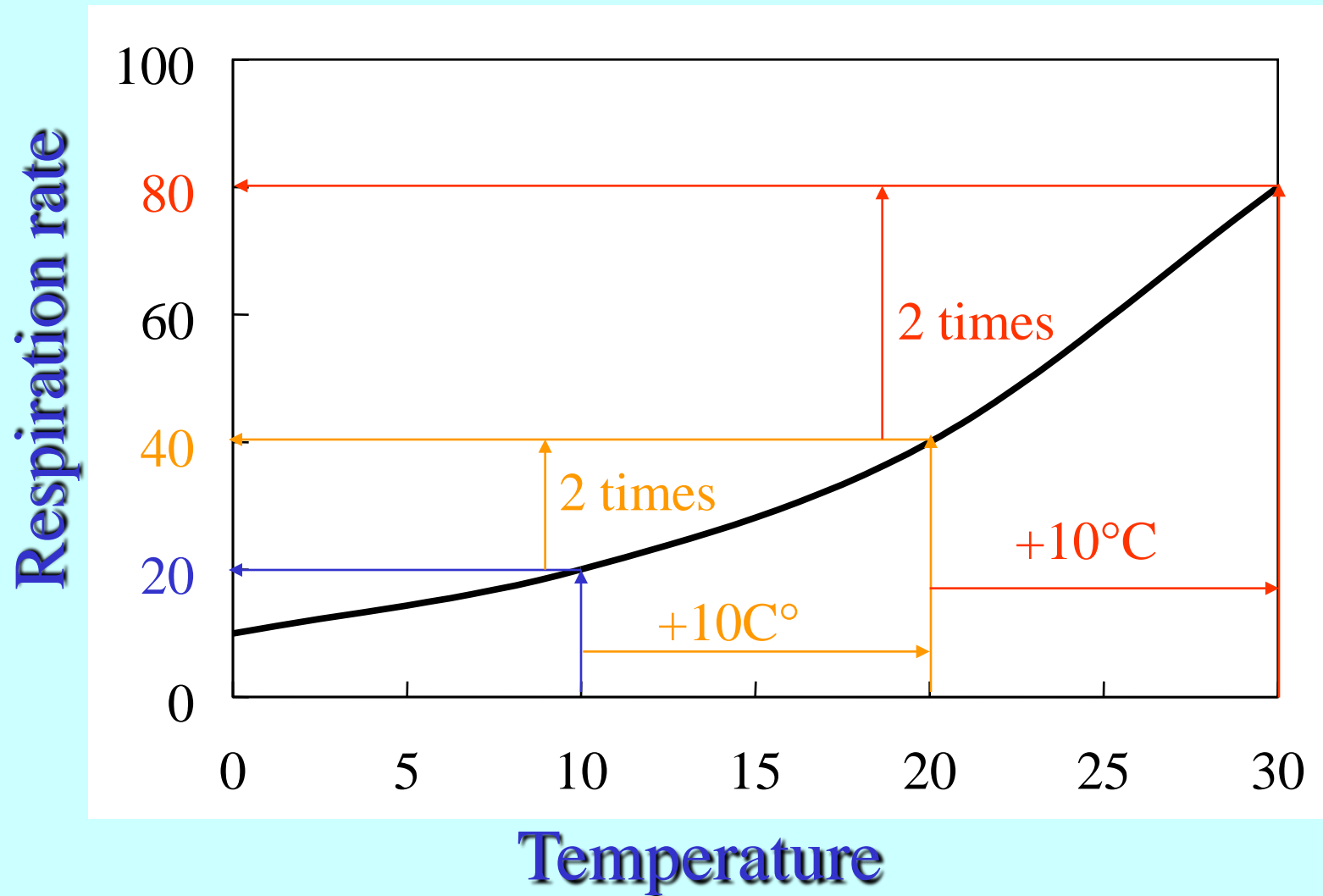
Wholesale markets play the central role in distributing the perishable foods (vegetables, fruits, fishes, meat, flowers etc.).

In Japan, more than 80% vegetable is distributed through the wholesale markets.

Effects of Low Temperature

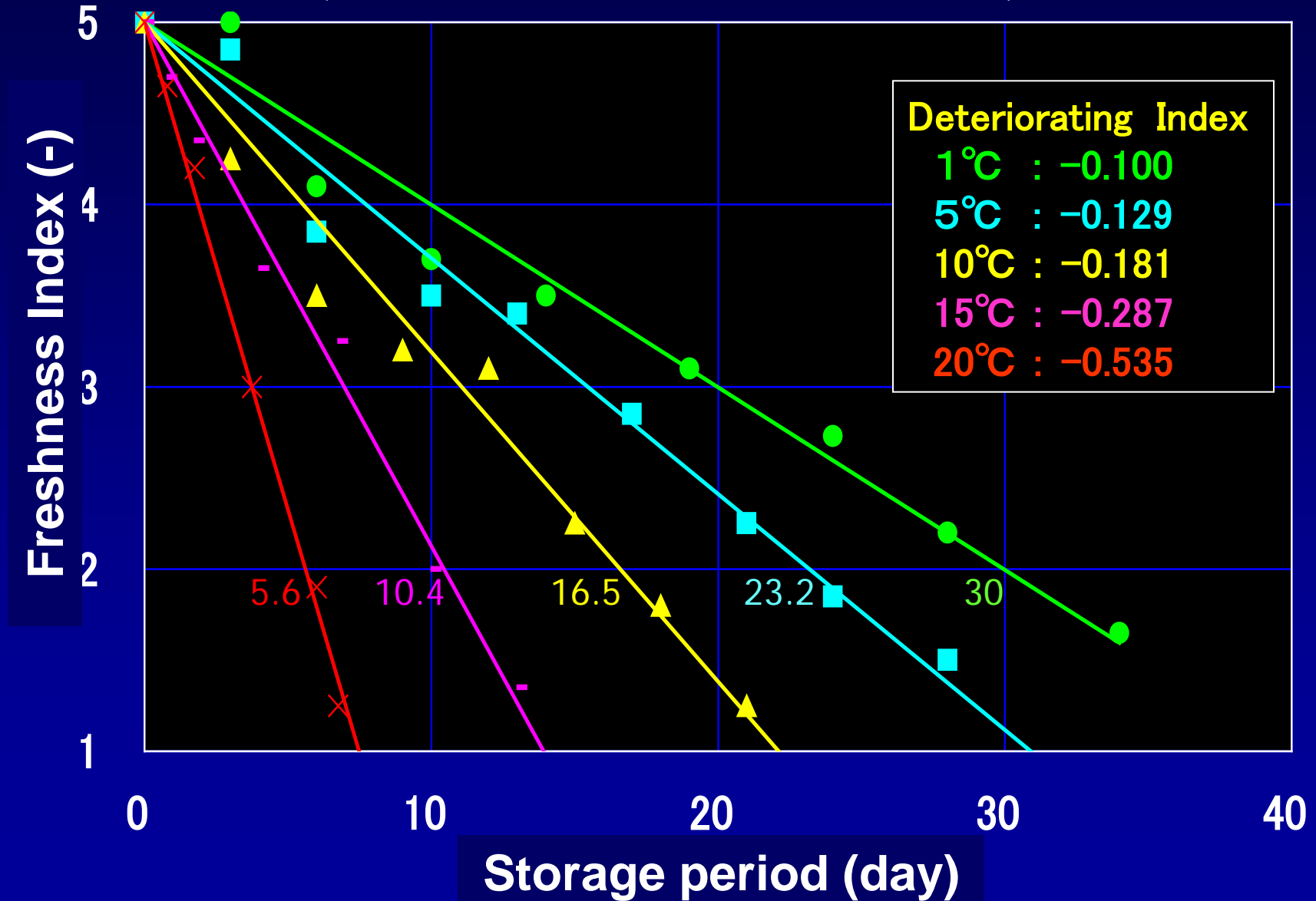
- Reduction of respiration rate, rate of quality change, weight loss, etc.-

Effect of temperature on the respiration rate (temperature coefficient, $Q_{10}=2.0$)



Effect of storage temperature on the freshness index of pea pod

(Obtained from the data of Ito et al., 1996)



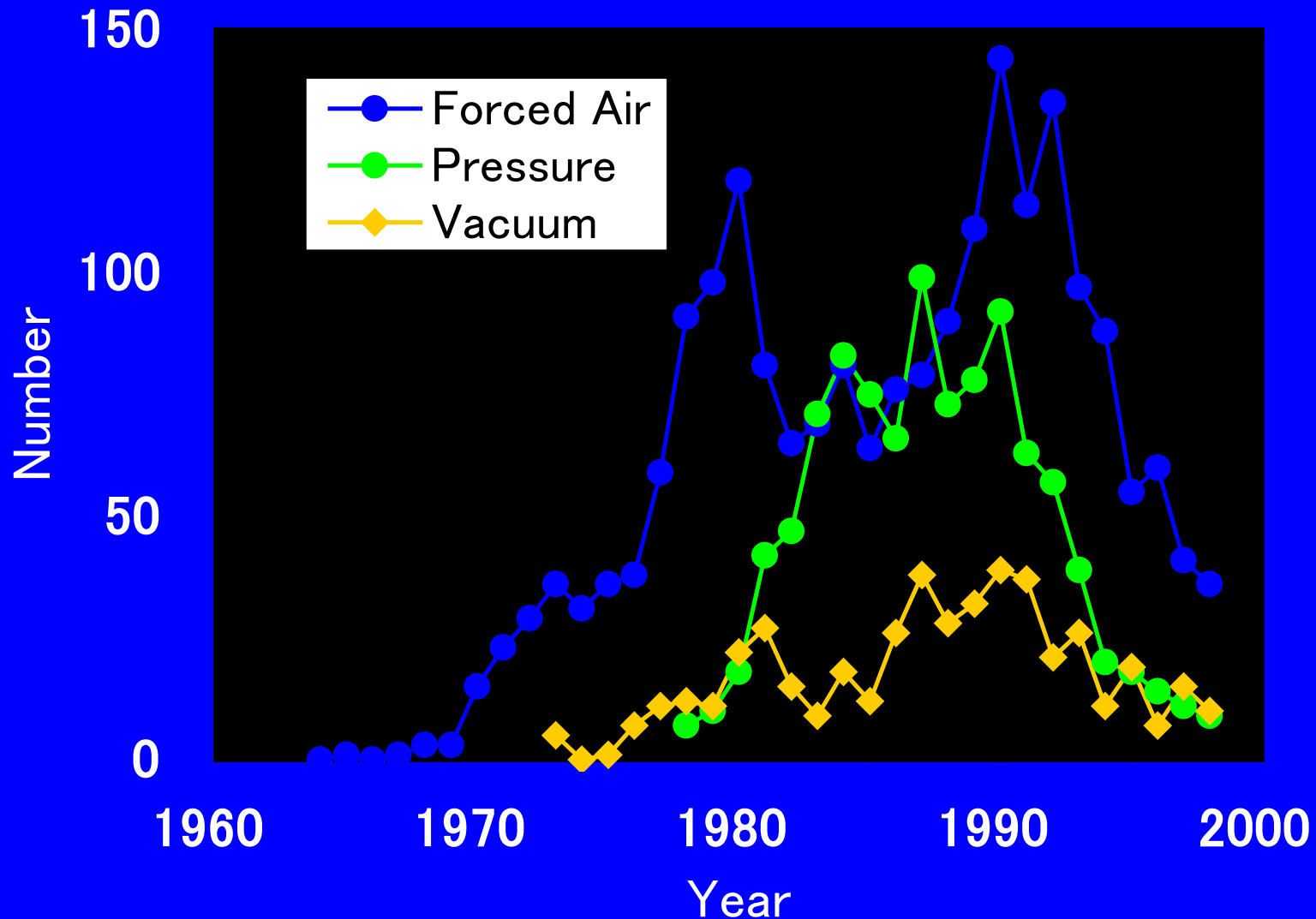
Precooling Methods in Japan

- Room cooling (in the storage room)
- **Forced air cooling** (Called as "Room cooling" in many other countries)
- Water cooling
- **Vacuum cooling**
- **Pressure cooling** (Called as "Forced air cooling" in many other countries)

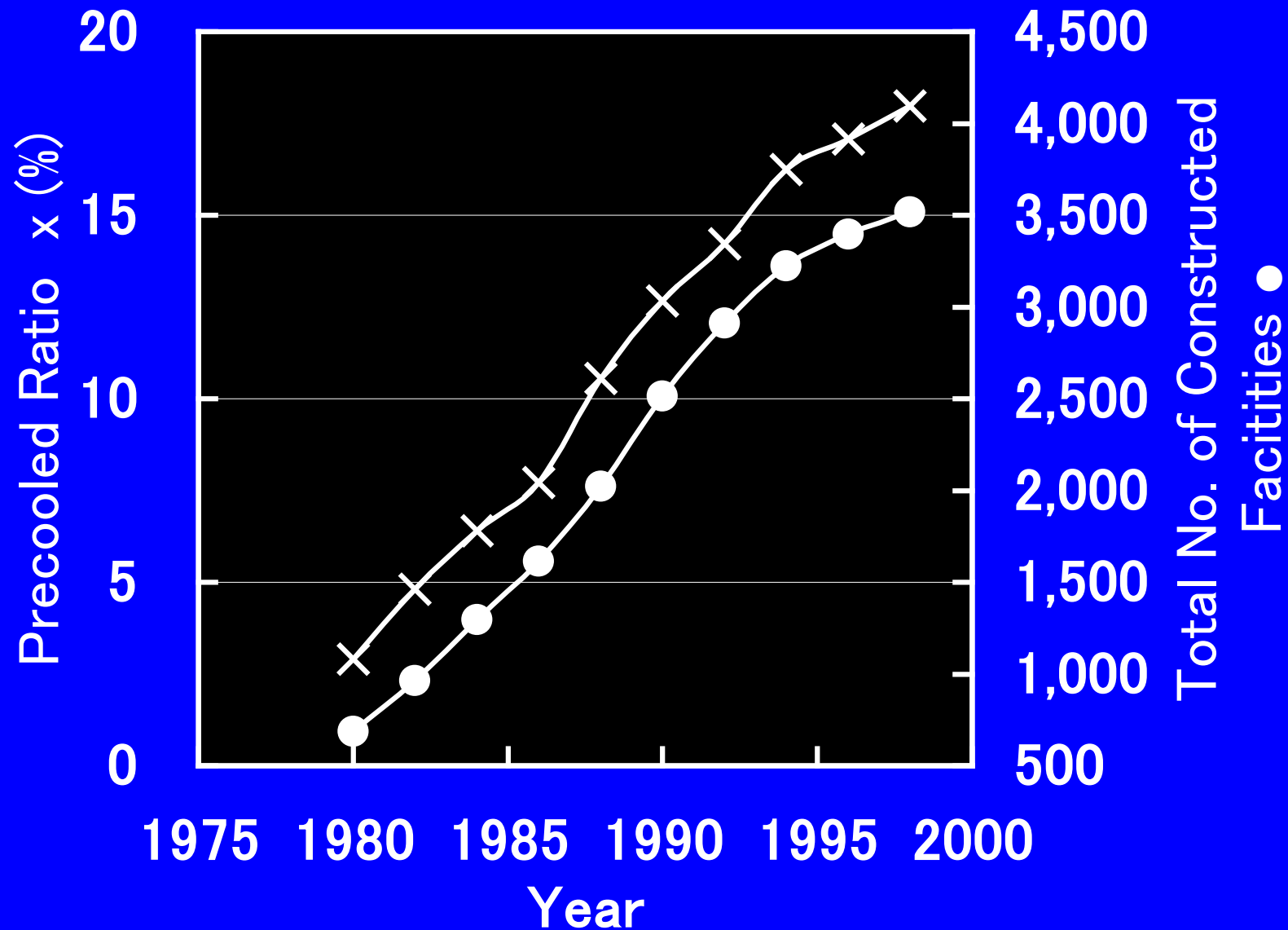
Characteristics of Common Precooling Methods in Japan

- **Vacuum Cooling**
 - quick and uniform cooling (evaporative cooling)
 - high cost, limitation of the commodity (leafy vegetables)
- **Forced-air Cooling**
 - slow cooling (indirect heat exchange)
 - lowest cost, no limitation of the commodity
- **Pressure Cooling**
 - faster than forced-air (direct heat exchange)
 - low cost, labor intensive, no limitation of the commodity

Precooling facilities in Japan (year wise construction)



Trends of the ratio of vegetables shipped after precooling and of the precooling facility



Effect of cooling method on the temperature change

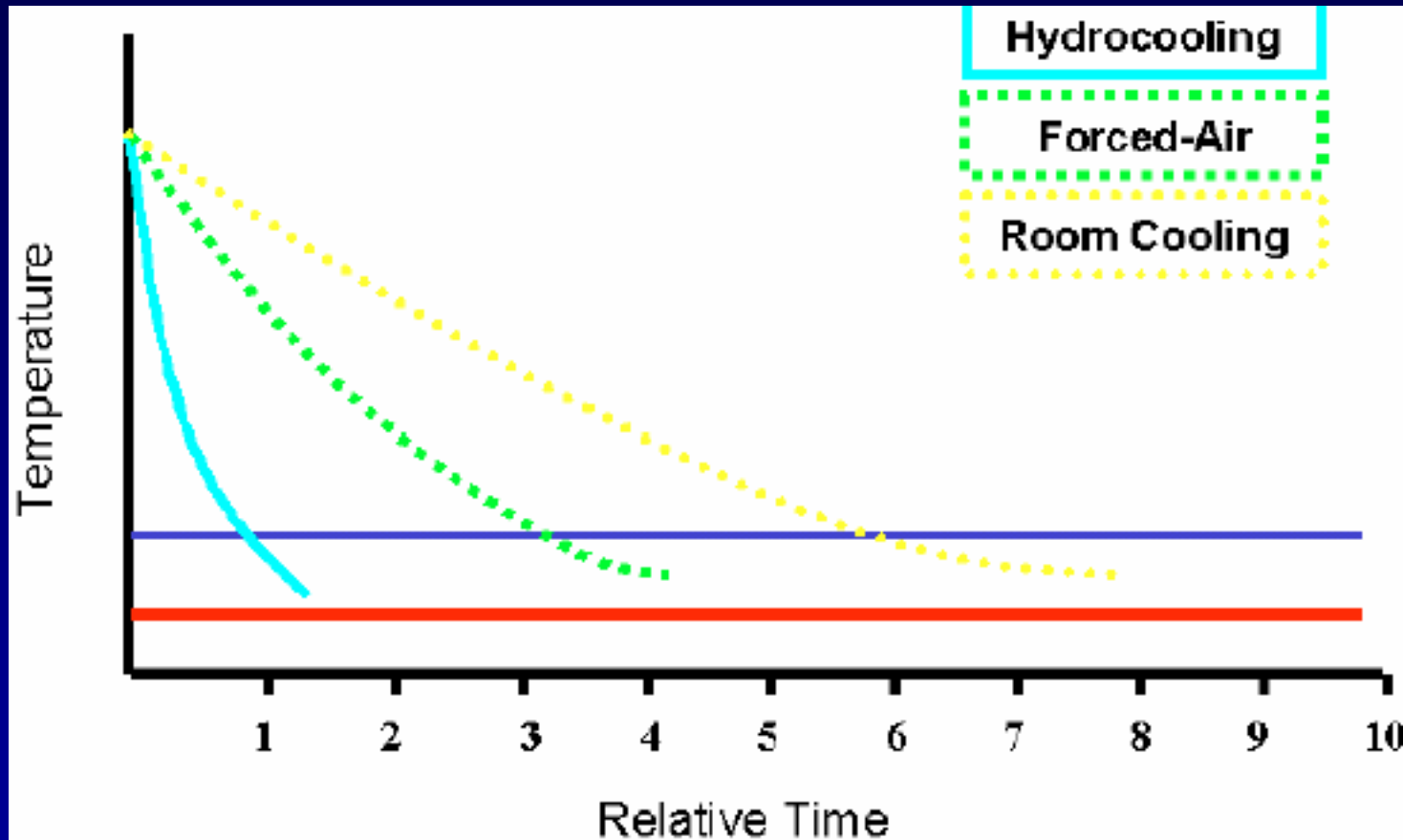
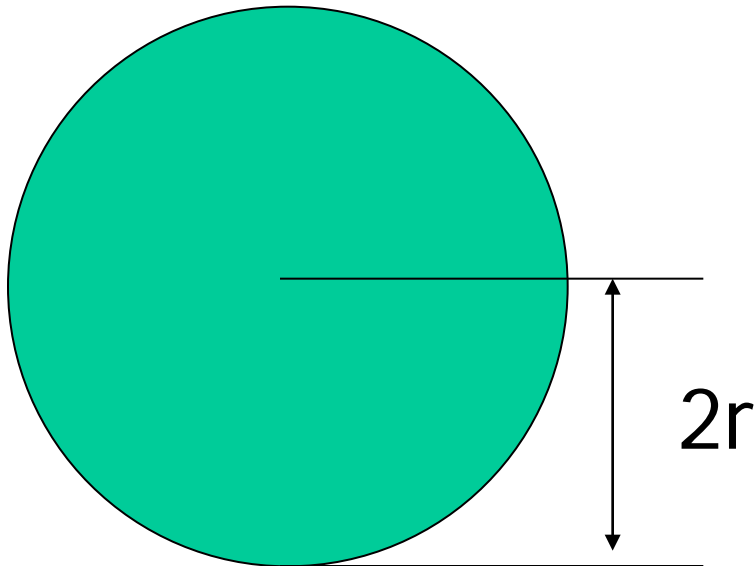
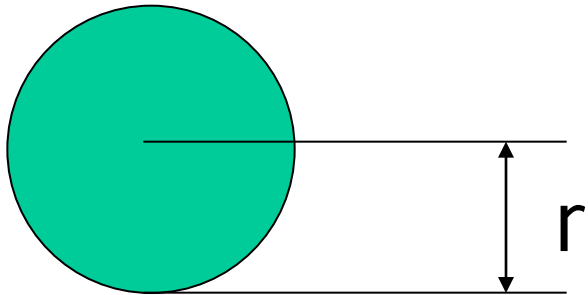


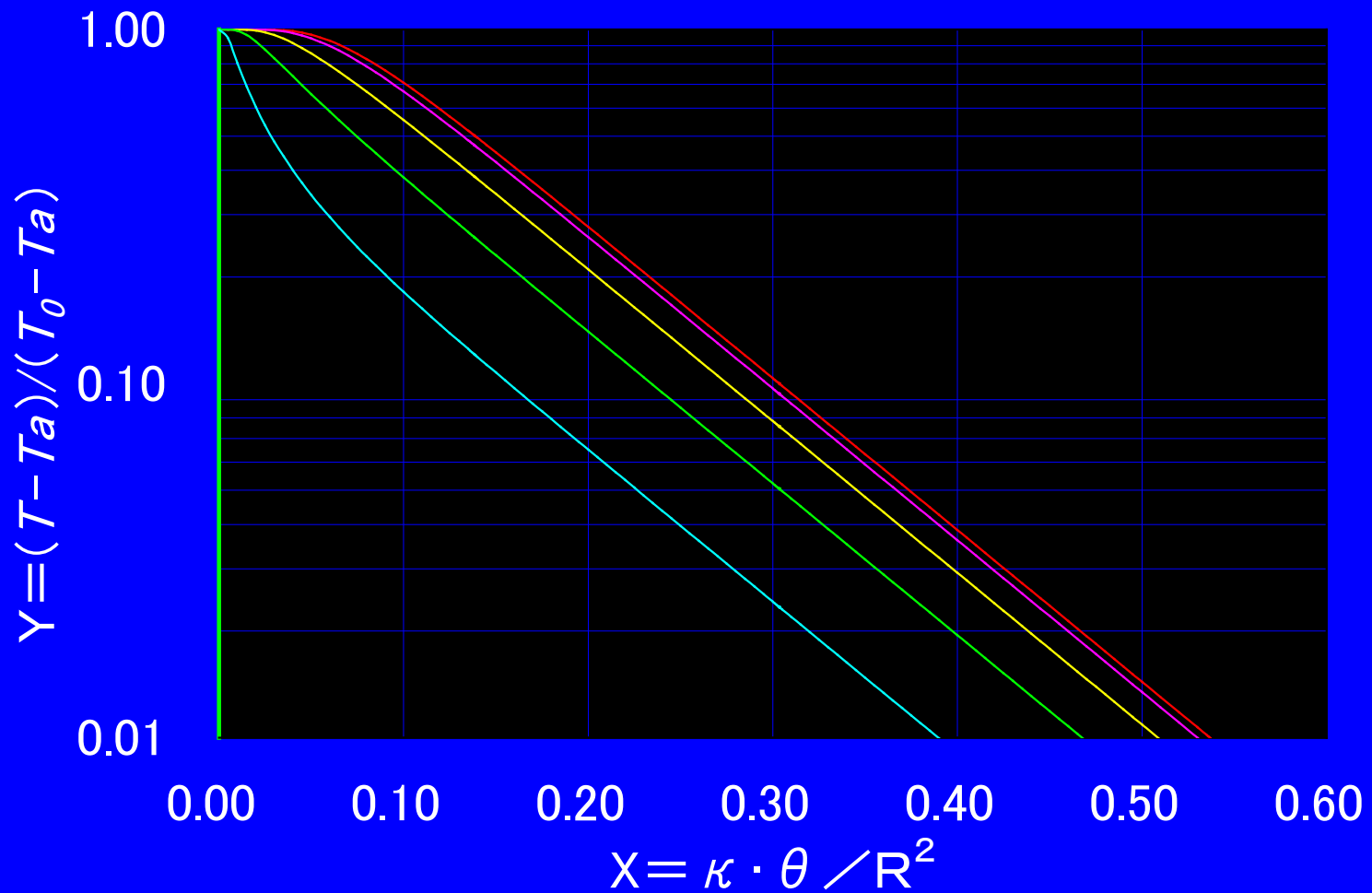
Fig. 1 Comparison between different precooling methods. Reprinted from: Palmer M (1999) Forced Air Cooling, Information kit No. 11, 8 pp, ©1999, with kind permission of the South Australian Research and Development Institute.

Effect of the fresh produce size on the cooling rate

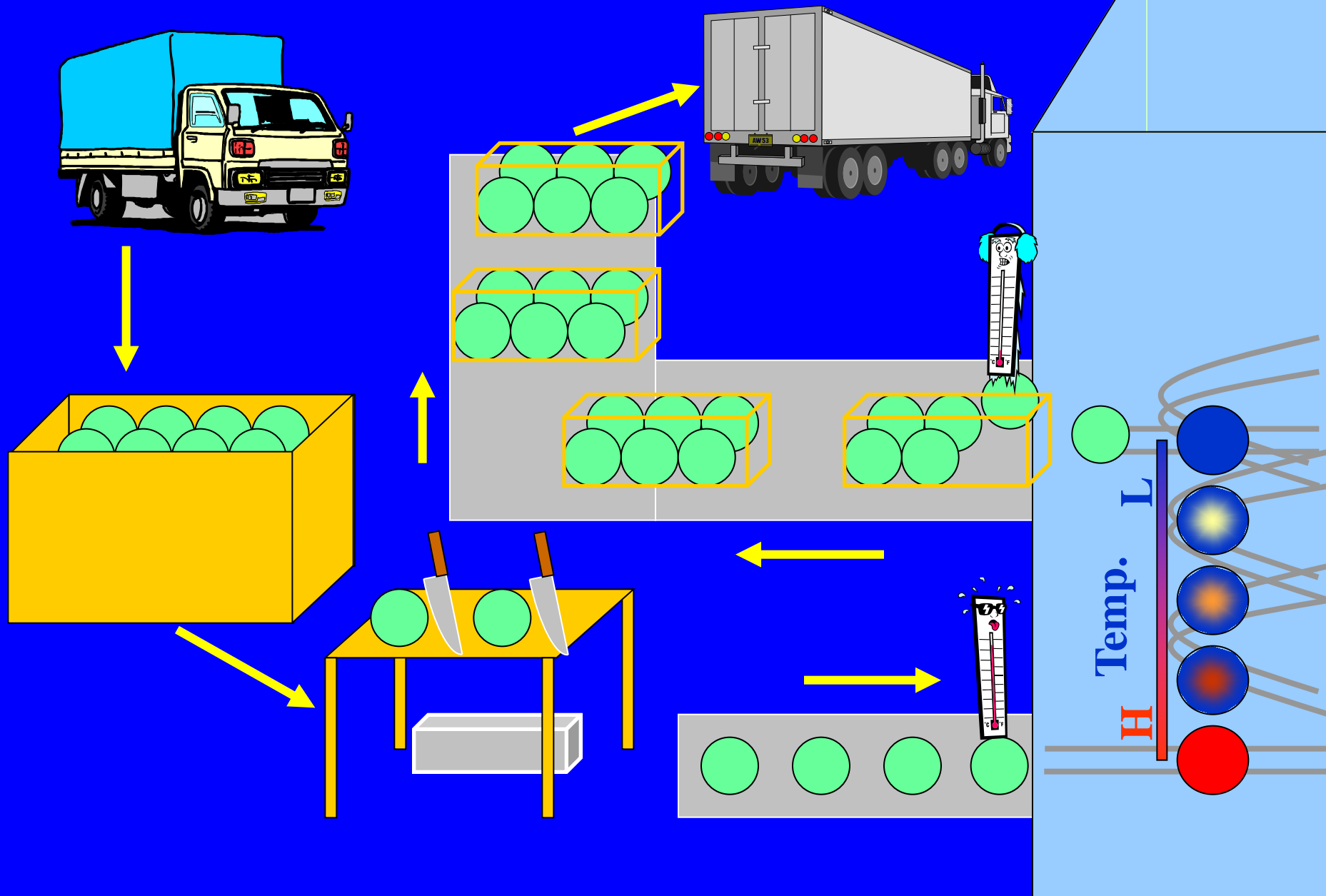


Size	Time for precooling
r	T
$2r$	$2^2T=4T$

Relationship between dimensionless time and dimensionless temperature ($\kappa = \lambda / C_p \rho$).



Schematic of the Individual Quick Cooling, IQC



Individual Quick Cooling, IQC

- Cool the produce individually by air without packaging and bulk stacking
- Avoid heat resistance from packaging materials and also from the surrounding produce.
- Simplifies the cooling process, and provides an ease in predicting the temperature profile by theoretical analysis
- Could be a promising method which can provide a quick, uniform, and automated precooling of perishables.
- In order to develop a design procedure of IQC process, knowledge of the cooling profile is essential

Effects of High Humidity

-Reduction of weight loss and keeping
freshness-

Effects of Important Parameters on the Rate of Water Loss (Evaporation)

Vapor Pressure Deficit
Produce Surface – Surrounding

X

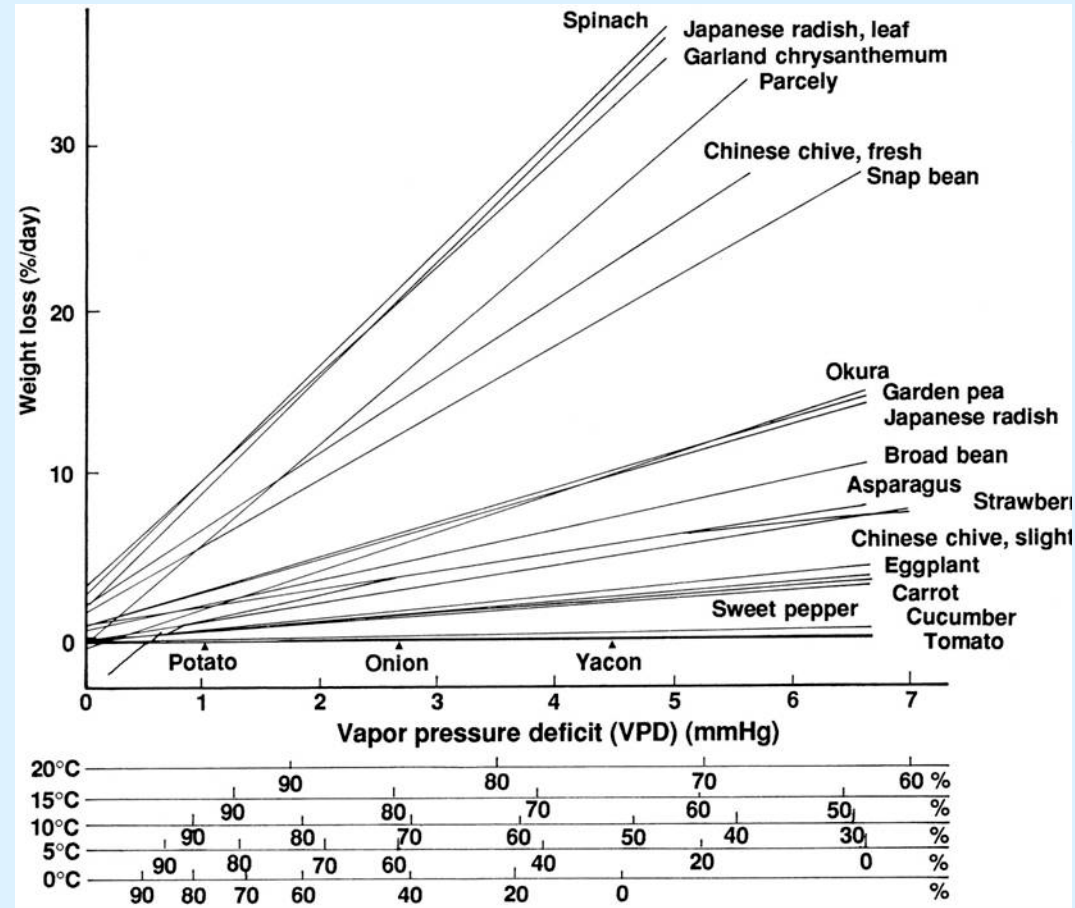
Specific Area

X

Transport Coefficient



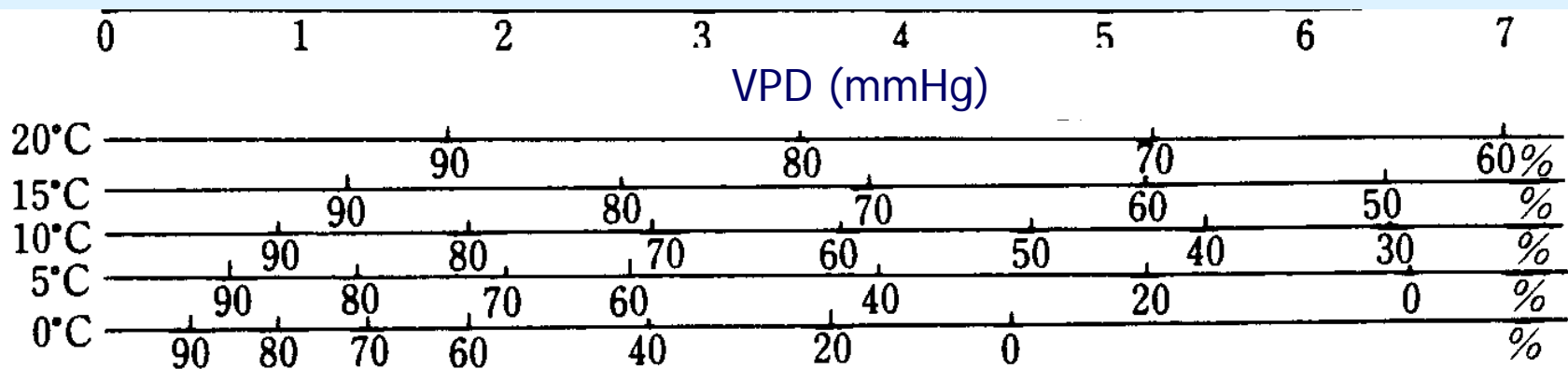
Evaporation Rate



Effects of Temperature and Relative Humidity on the VPD

VPD is the Difference of **Absolute Humidity** Between the Produce Surface and the Surrounding Air

Absolute Humidity is the mass of vapor in the air, and is the **Function of** Temperature and Relative Humidity

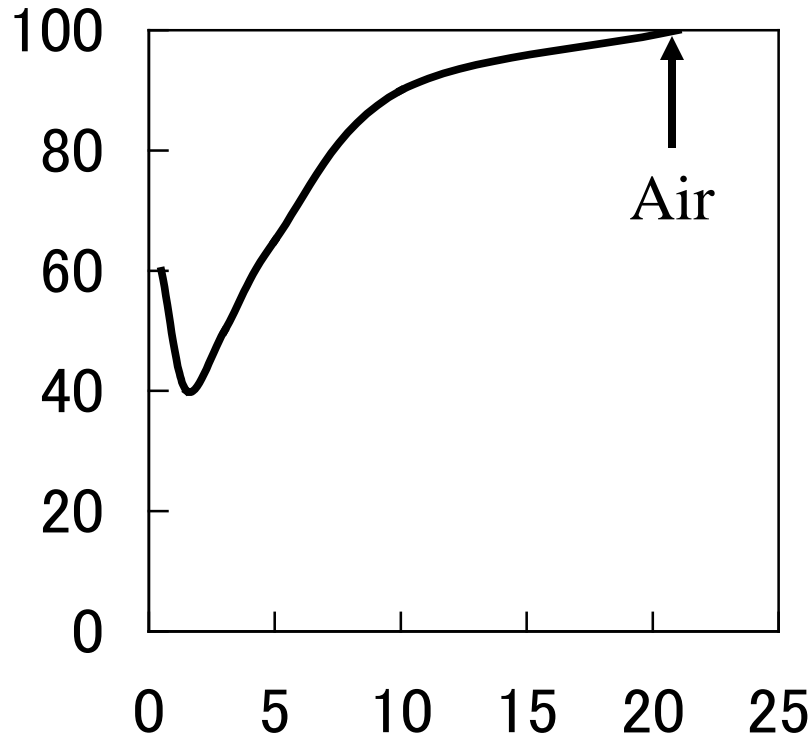


Effects of the Gas Modification

- Reduction of respiration rate, rate of quality change, etc.-

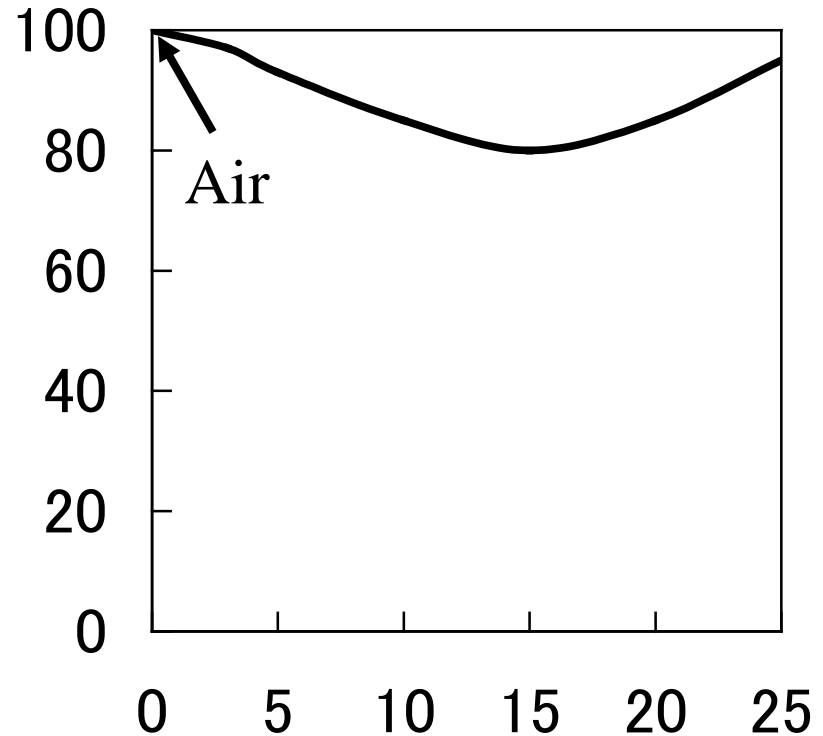
Effects of O₂ and CO₂ Concentration on the Respiration rate

Relative Respiration



O₂ Concentration(%)

Relative Respiration

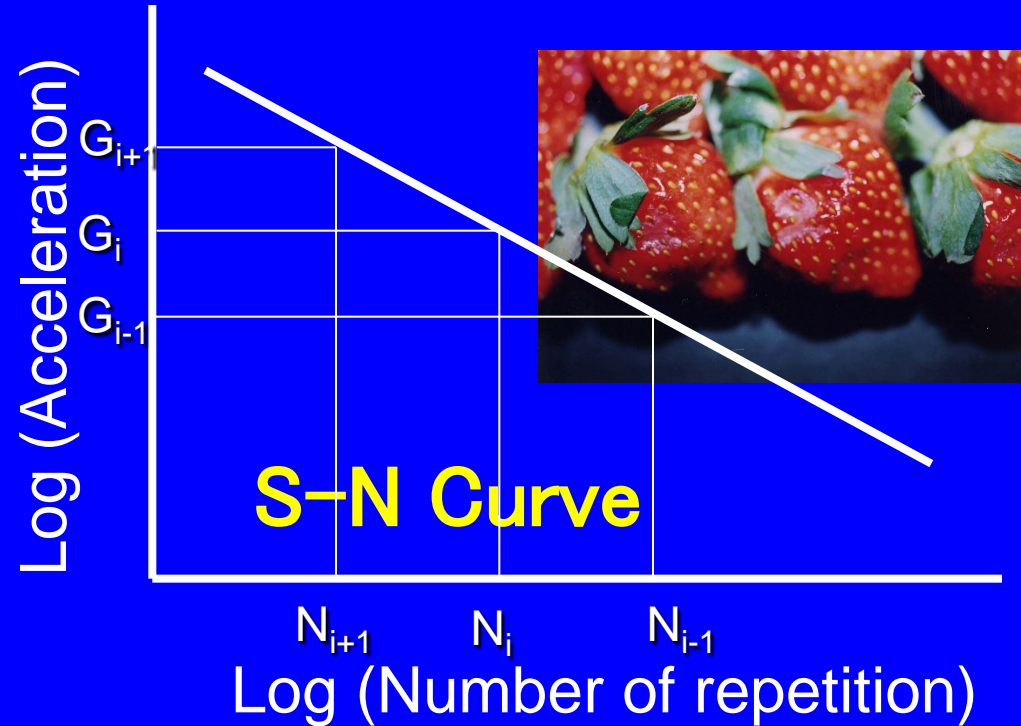
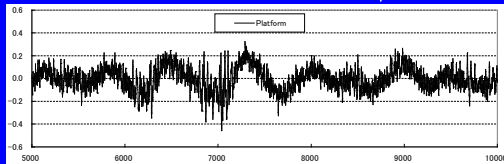
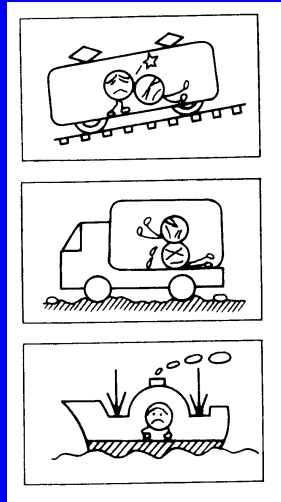


CO₂ Concentration(%)

Effects of Appropriate Cushioning by Transport Simulation Method

- Reduction of physical damage -

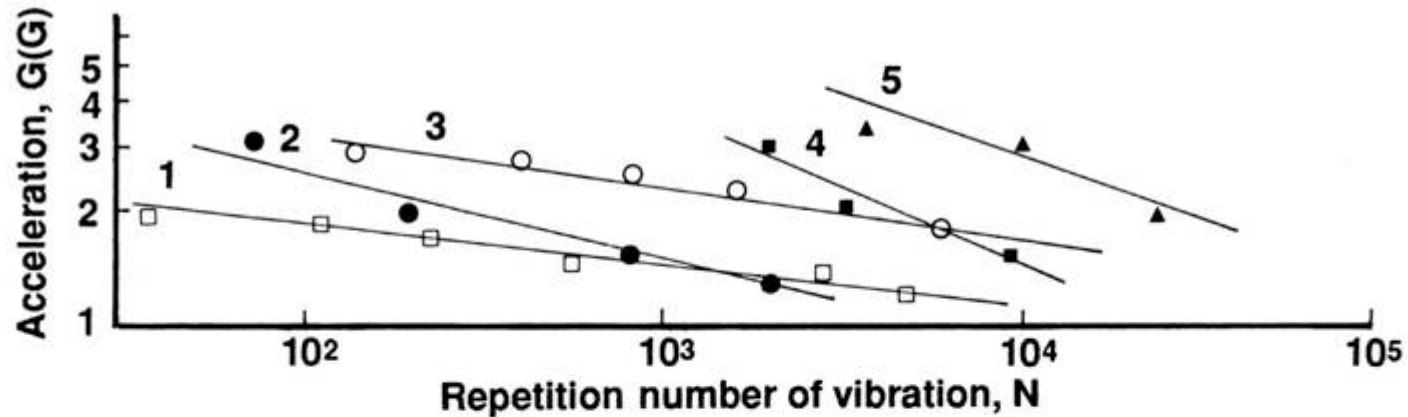
Transport Simulation Method



Same level of the damage as the actual transport

Frequency, Time and Acceleration level

S-N Curves for several F&V



Product	Form of package	α	β
1. Strawberry	PVC package, bulk packaging (300 gx4)	9.26	2.65×10^4
2. Lettuce	Cardboard box, two-tier packaging (10 kg)	4.17	5.32×10^3
3. Grape	Cardboard box (4 kg)	6.99	4.13×10^5
4. Peach	PVC package, cardboard box (5 kg)	2.44	2.46×10^4
5. Japanese pear	PSP package, cardboard box (15 kg)	3.00	2.27×10^5

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Transport Mode

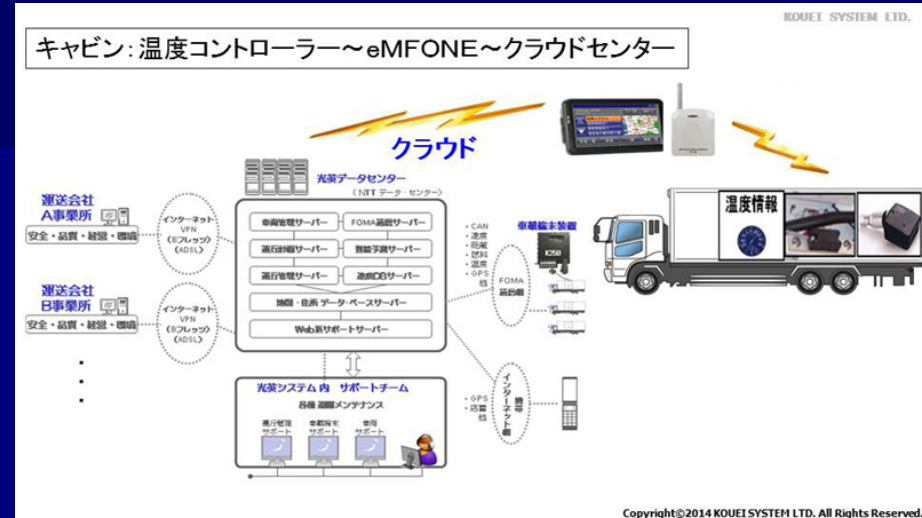
- Truck Transport
- Rail Transport
- Sea Transport
- Air Transport

Truck Transport

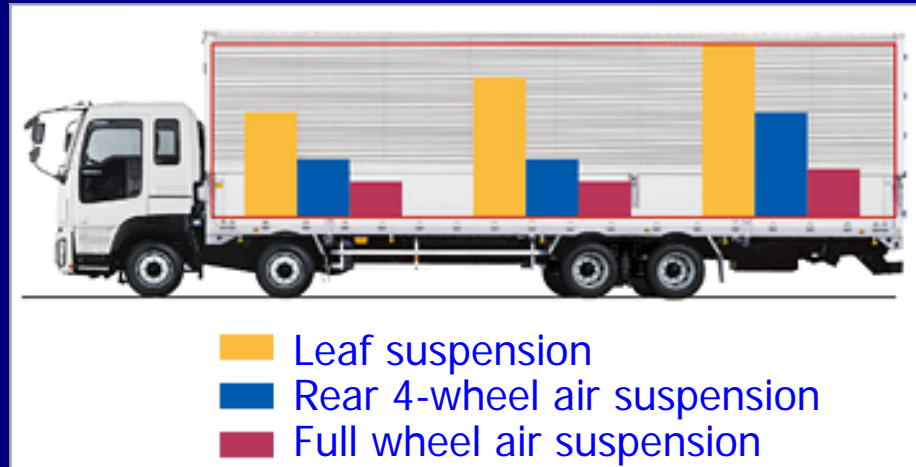
- Multi-temperature control
- Data Loggers
- Real time environment monitoring
- Simulated-product temperature monitoring
- Reducing shock & vibration



[http://www.dtijapan.co.jp/index.php/
usb-data-logger-with-glycol-bottle](http://www.dtijapan.co.jp/index.php/usb-data-logger-with-glycol-bottle)



<http://lnews.jp/2014/07/g070701.html>

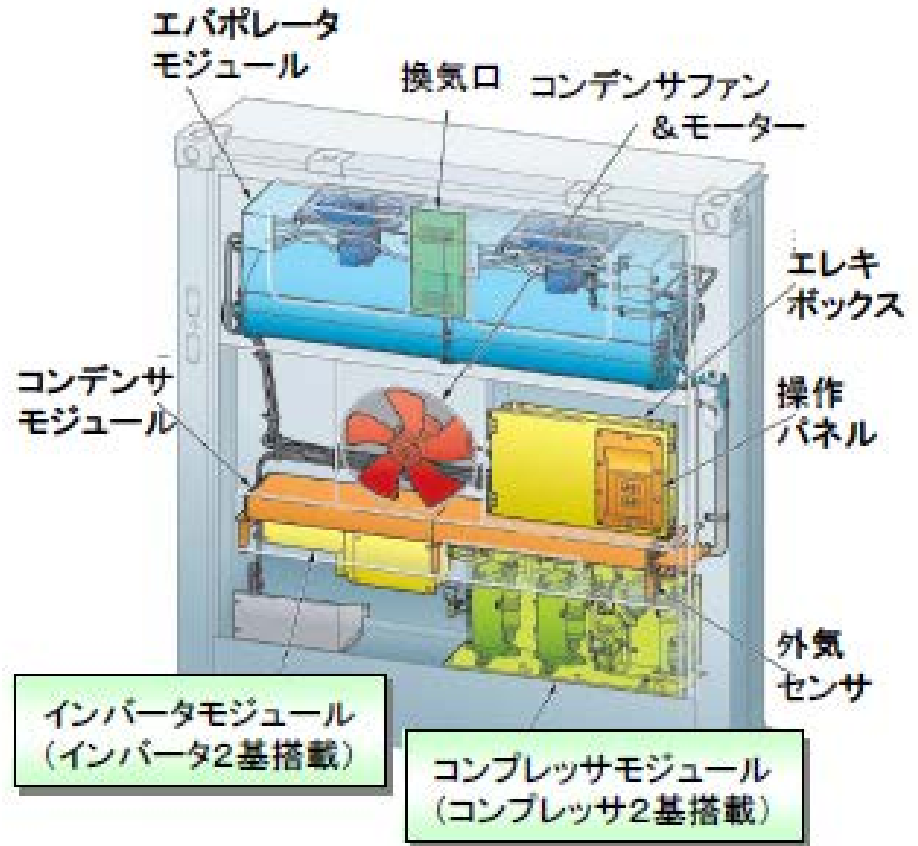


<http://www.isuzu.co.jp/product/giga/4airsus/fullairsus.html>

Rail Transport

- "Cool Container": Refrigerated container for rail transport
- for International freight transport
- Size matching of JR Container (Japan Freight Railway Company) to the Intermodal container

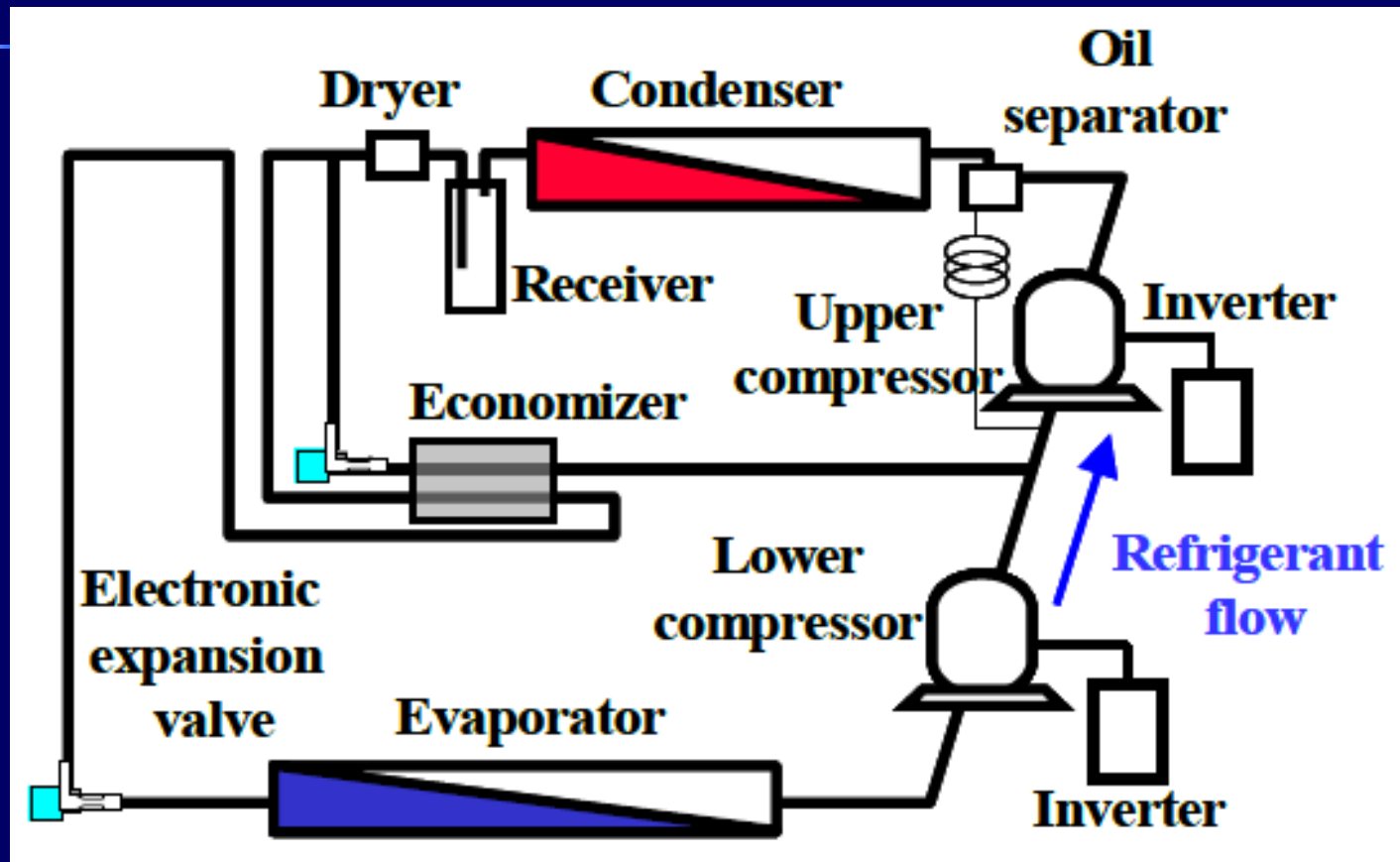
Sea Transport (Freight)



Two compressor and two inverter system for refer container

(Takizawa et al., 2014)

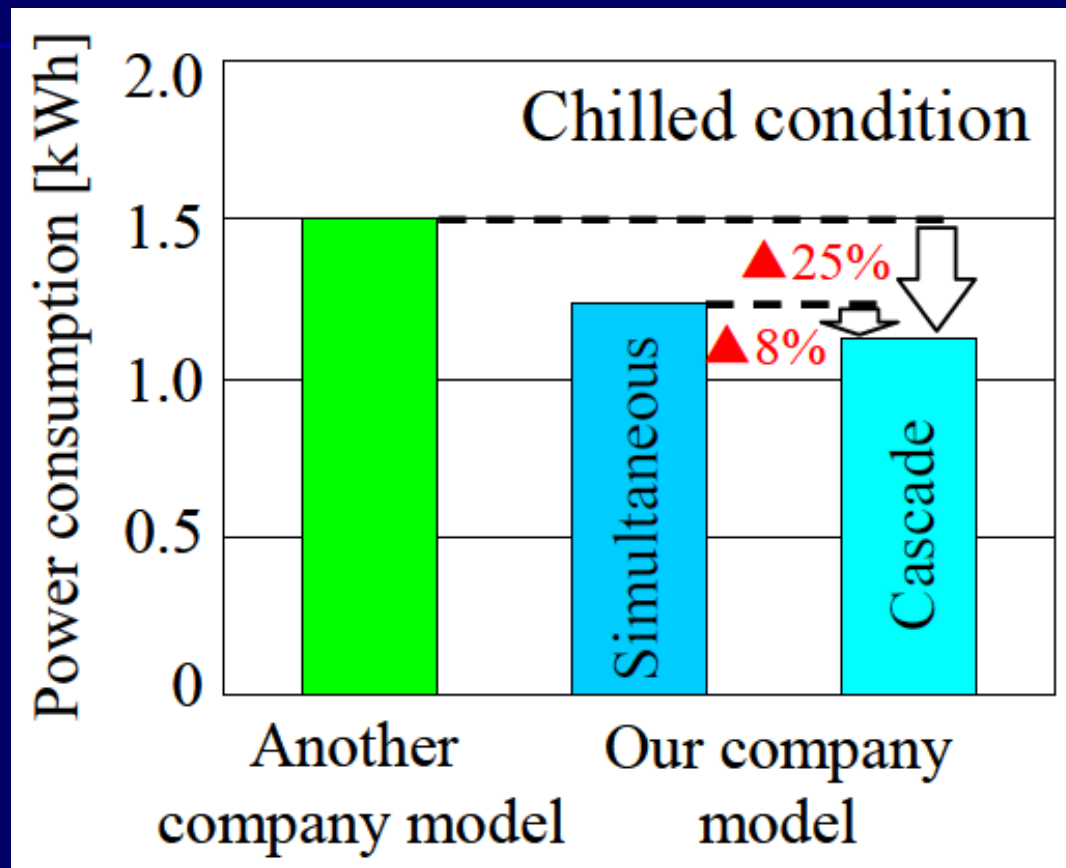
COP maximization by controlling the degree of superheat of refrigerant at the low temperature outlet of economizer using electronic expansion valve



System diagram

(Takizawa et al., 2014)

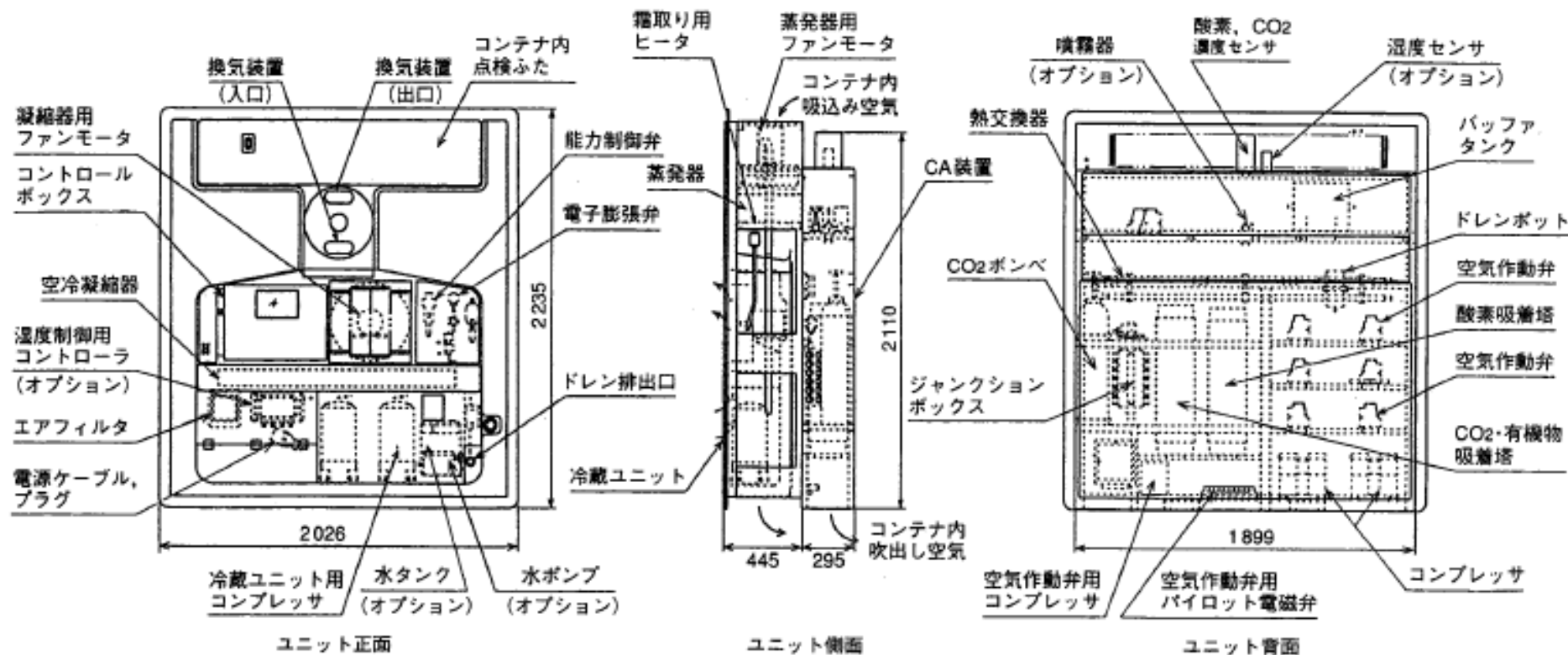
Effect of new cooling system on the reduction of energy use



System diagram

(Takizawa et al., 2014)

Temperature and gas control unit for Controlled Atmosphere container



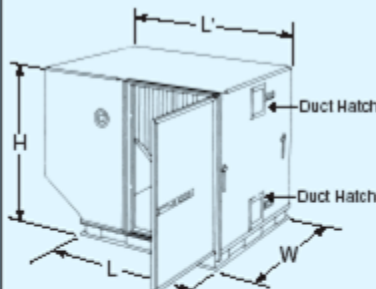
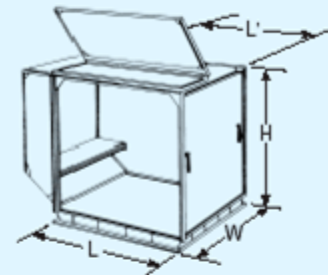
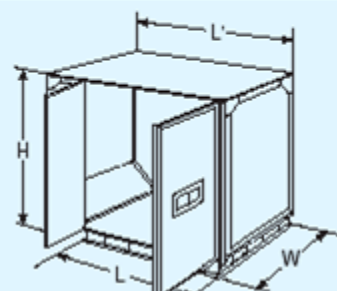
Air Transport (Traditional system)

in the case of JAL Cargo

Cold air flashing type
(with heat insulation panel)

Heat insulation type

Dry ice type
(with heat insulation panel,
dry ice gas separated)

Base Size	IATA I.D. Code (ATA Code)	Illustration イラスト	Int Volume 内容量: m ³ (ft ³)		Loadable Aircraft & Comp't 搭載可能 機種 & 貨物室	Weight Limitation Inc ULD Tare Wt 重量制限 含 自重 kg (lb)	
			L W H	External Dimension 外寸 cm (in)			Internal Dimension 内寸 cm (in)
			Tare Wt 自重: kg (lb) *Including NET WT				Capability 性能諸元
60.4" X 61.5"	MVN (LD-3)		3.7 (131)		See DKN/DVN		
			L	157 (62)	132 (52)	(1) Thermal Insulated 保冷 (2) No Temp Control 温度管理不可 (3) Coolant: COOL AIR/ DRY ICE 冷風ユニット使用	
			L'	200 (79)	177 (70)		
			W	152 (60)	129 (51)		
			H	160 (63)	132 (52)		
	320 (705)						
	MKN MKNK (LD-3)		3.8 (134)		See DKN/DVN		
			L	157 (62)	137 (54)	(1) Thermal Insulated by Polystyrene panel at the inside surface 難易保冷 (2) No Temp Control 温度管理不可	
			L'	200 (79)	190 (75)		
			W	152 (60)	142 (56)		
H			162 (64)	147 (58)			
145 (320) ~ 154 (339)							
RKN (LD-3) MKNF DC		3.0 (106)		See AKN			
		L	157 (62)	124 (49)	(1) Refrigerated (保冷) (2) Inside Temp: -20° ~ +20° (-4°F ~ 68°F) (3) EH Temp: 72HRS (4) Coolant: DRY ICE 180k/396L (5) No Dry Ice Gass Inside MKNFのみ光熱線装置装着可		
		L'	200 (79)	180 (71)			
		W	152 (60)	124 (49)			
		H	162 (64)	132 (52)			
		220 (484) ~ 265 (583)					

Current line up including recent developments (rechargeable battery type)

■幅広いニーズに合わせた特殊輸送器材



Please visit the presentation of some of the advanced technologies provided by the companies attending

- セブンシップ社 (Seven Ship Co., Ltd)
<http://myqr.jp/landing/?key=sevanship>
- サラヤ社 (Saraya.Co.Ltd)
<http://www.saraya.com/>
- 住友ベークライト社 (SUMITOMO BAKELITE CO., LTD)
P-プラス開発部 (P-Plus)
<http://www.sumibe.co.jp/product/p-plus/index.html>
- 羽根社 (Hane)
<http://www.hane.co.jp/corp.html>
- ニッコー社 (Nikko Co., Ltd.)
<http://www.k-nikko.com/products/id360/>
- 鳥越製粉社 (THE TORIGOE CO., LTD)
<http://www.the-torigoe.co.jp/>

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Requirements of Value Chain

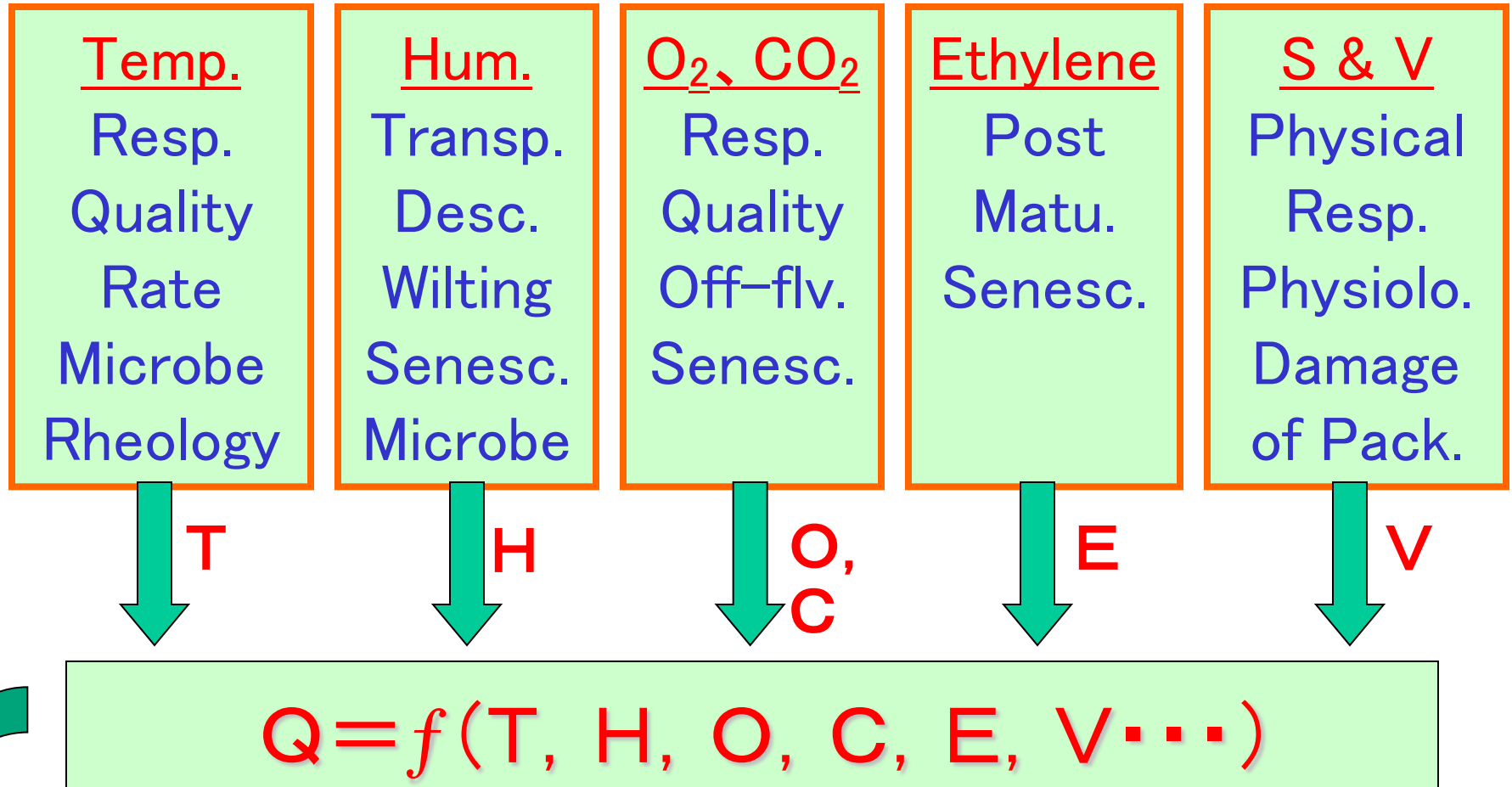
- Benefit to all stakeholders
- High quality (with reasonable price)
 - Quality assurance system
 - Cold Chain and other quality control measures
- Value addition
- Food safety
- Stable supply to eliminate food security risk

From "Cold Chain" to "Value Chain" based on the quality assurance system

- Integrate the food quality control system based on the "Cold Chain"
 - Implementation of other quality control measures such as CA, MA, High humidity, new technologies, and so on onto the cold chain system
- Building partnerships
- Technology and Knowledge transfer

Quality Assurance by TET*

*TET: Time Environment Tolerance



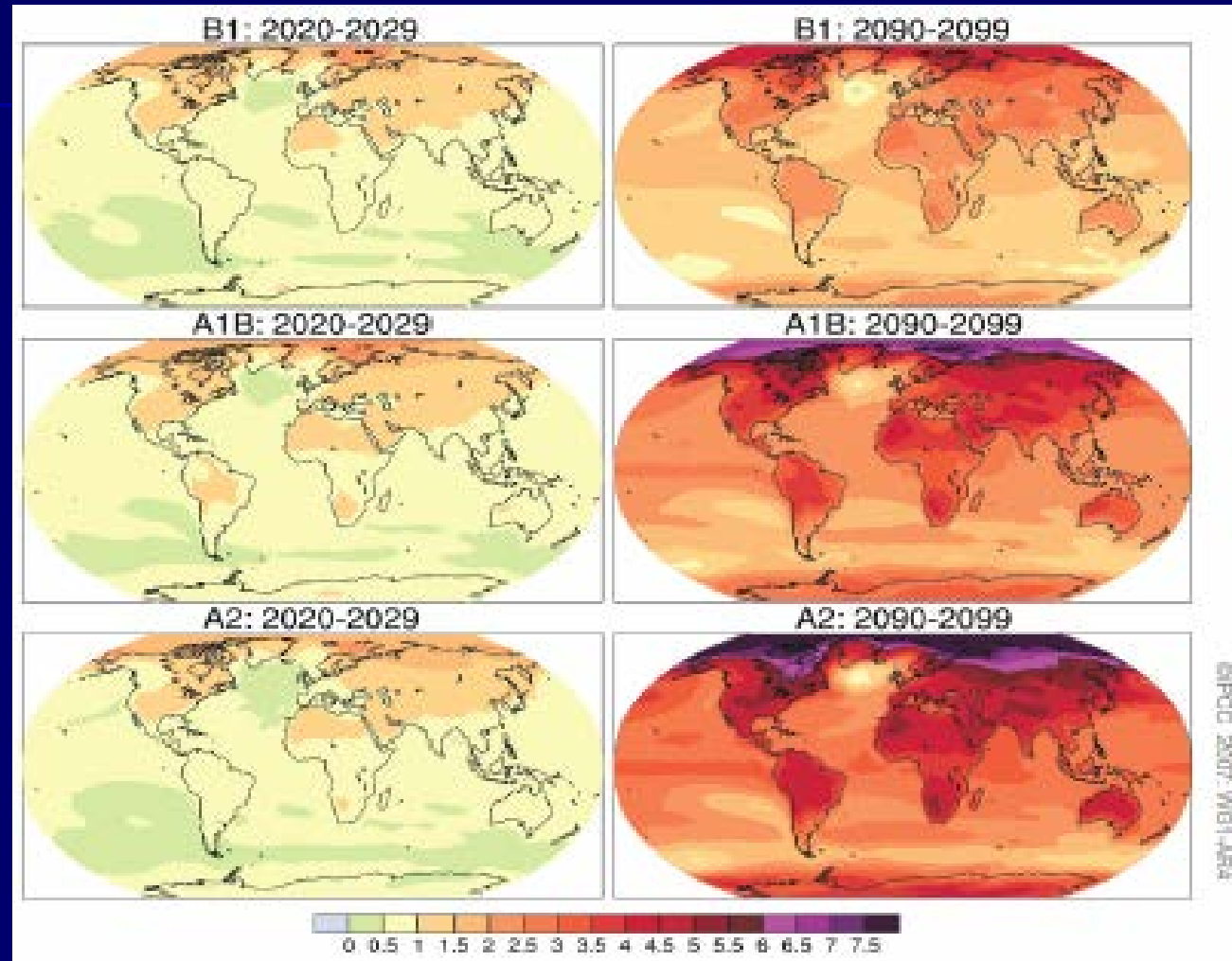
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Estimation of Global Warming

IPCC reported the estimation of the global warming based on the several scenarios.

It can be seen that the increase in temperature depends on the scenarios employed and the location of globe.

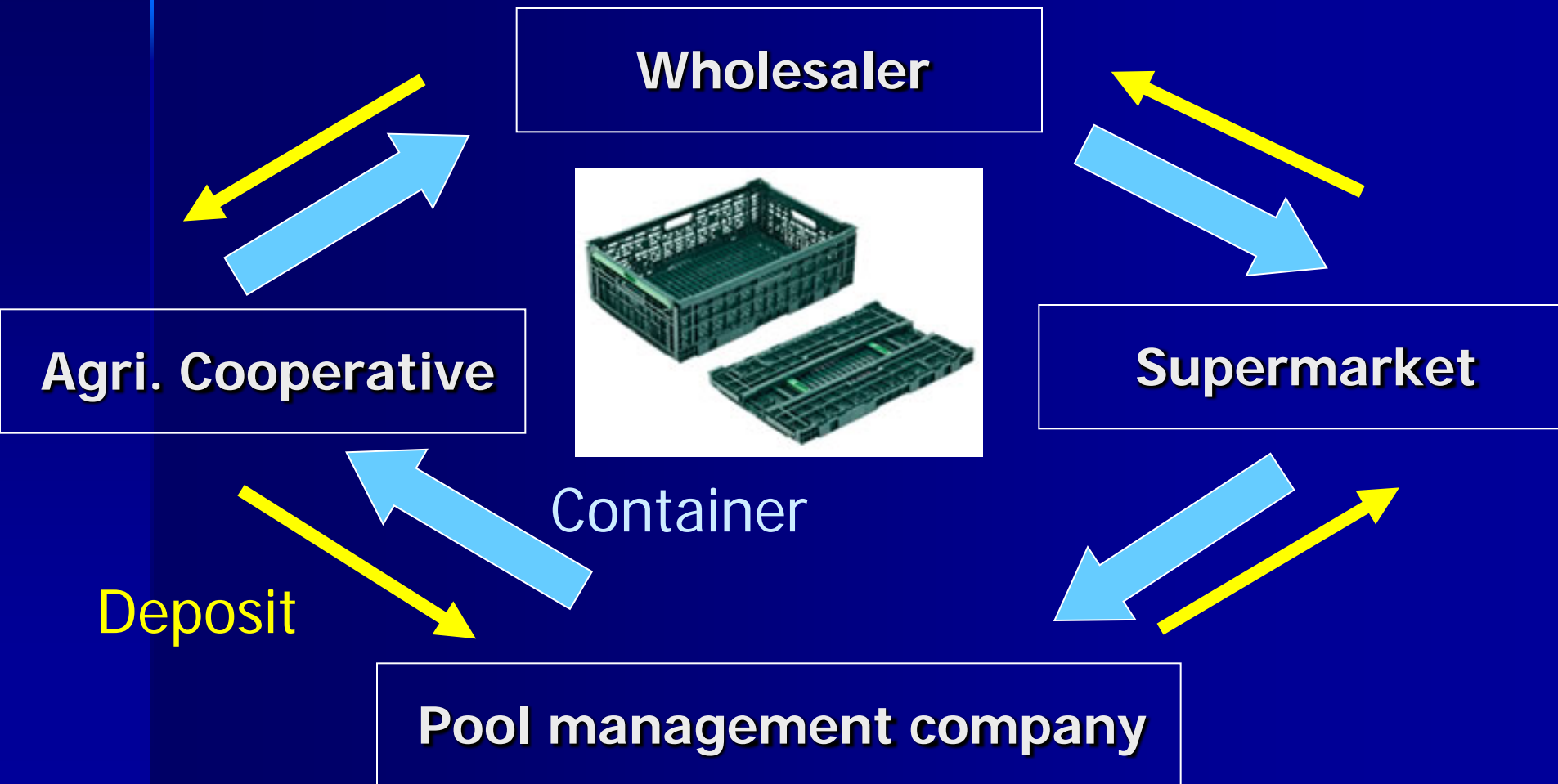


Scenario based analysis of the global warming from the year 1980-1999 (A2, A1B, B1) (IPCC,2007)

3 Rs

- Reduce
- Reuse
- Recycle

Pool management system in Japan for reuse container



Research Project on the Technology Development of Bulk Container Distribution System for Low-cost and Less-Environmental Impact (Project No.22014)

Characteristics of New Bulk Container

- JIS Module Size: 1.1*1.1(m)*Free
- Palette Lid: Plastic (Reuse)
- Slive: Corrugate Fiberboard Box (Reuse)
- Merits: Low cost, Less GHG
- Usage: Goods for Automobile

Not in Use for Fresh Produce

Large volume
Efficient Handling
(50 times of CFB)

**Effectiveness
in Reuse**
(Reduce to 1/7)



Reuse

**Use for Fresh
fruits and
Vegetables**

**Technology
development
to enable reduced
cost and environ-
mental load**

Development of
Environmentally
Friendly and Low
Cost Distribution
System for
Fresh Fruits
and Vegetables

Lab. tests, Modeling,
Transport test and LCA

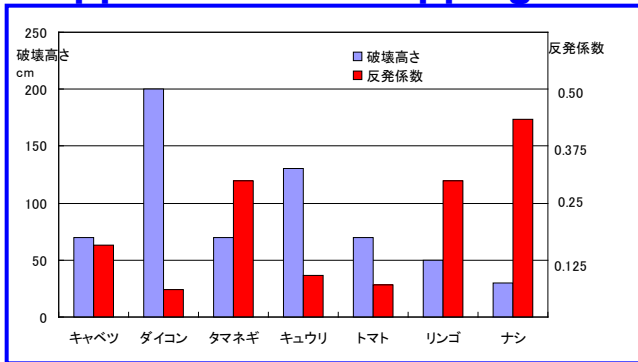
Physical Damages
Quality deteriorations



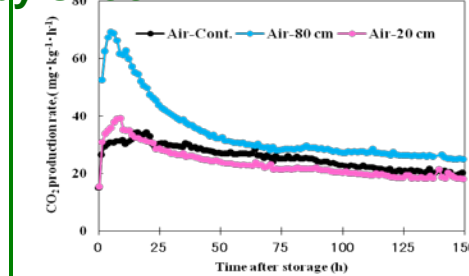
1. Reduction of Physical Damage

2. Reduction of Physiological Damage

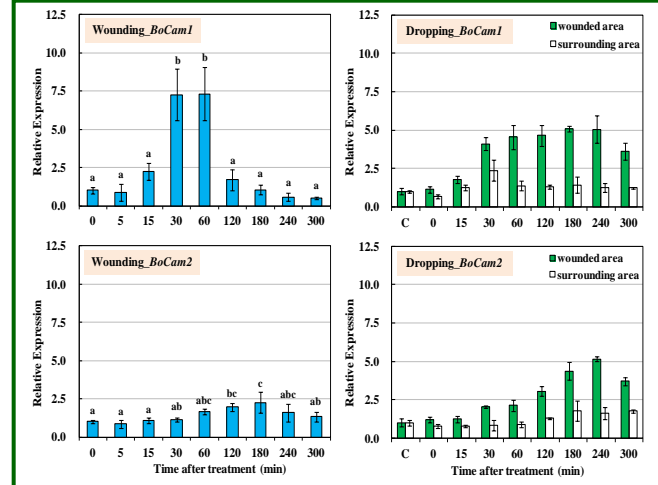
Upper Limit of Dropping



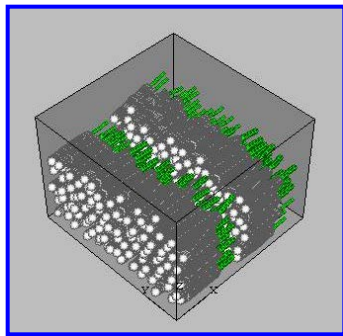
Change in Respiration rate by shock



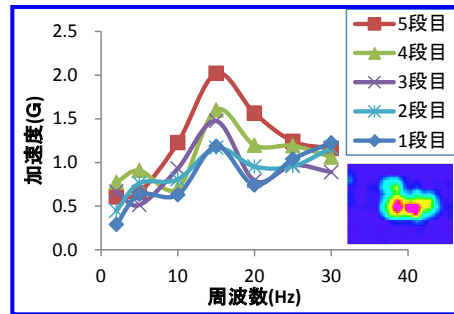
Modulation of gene expression



Discrete Element Method (DEM)



Transmissibility, Force, Damage by Vibration



Damage

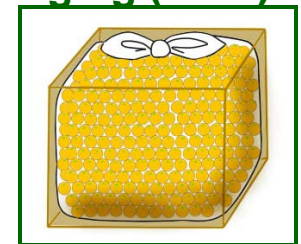


Physical Damage Reduction

Physiological Damage reduction

Selection of Variety

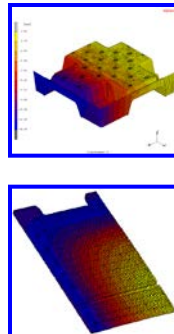
Modified Atmosphere Packaging (MAP)



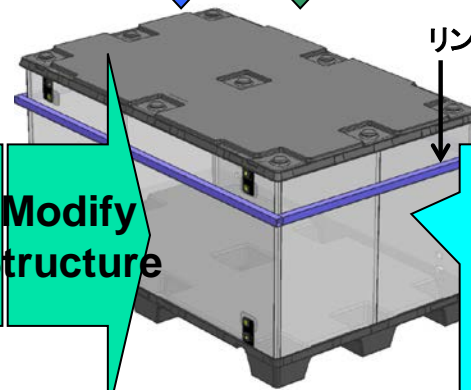
Transport Test



CAE, FEM



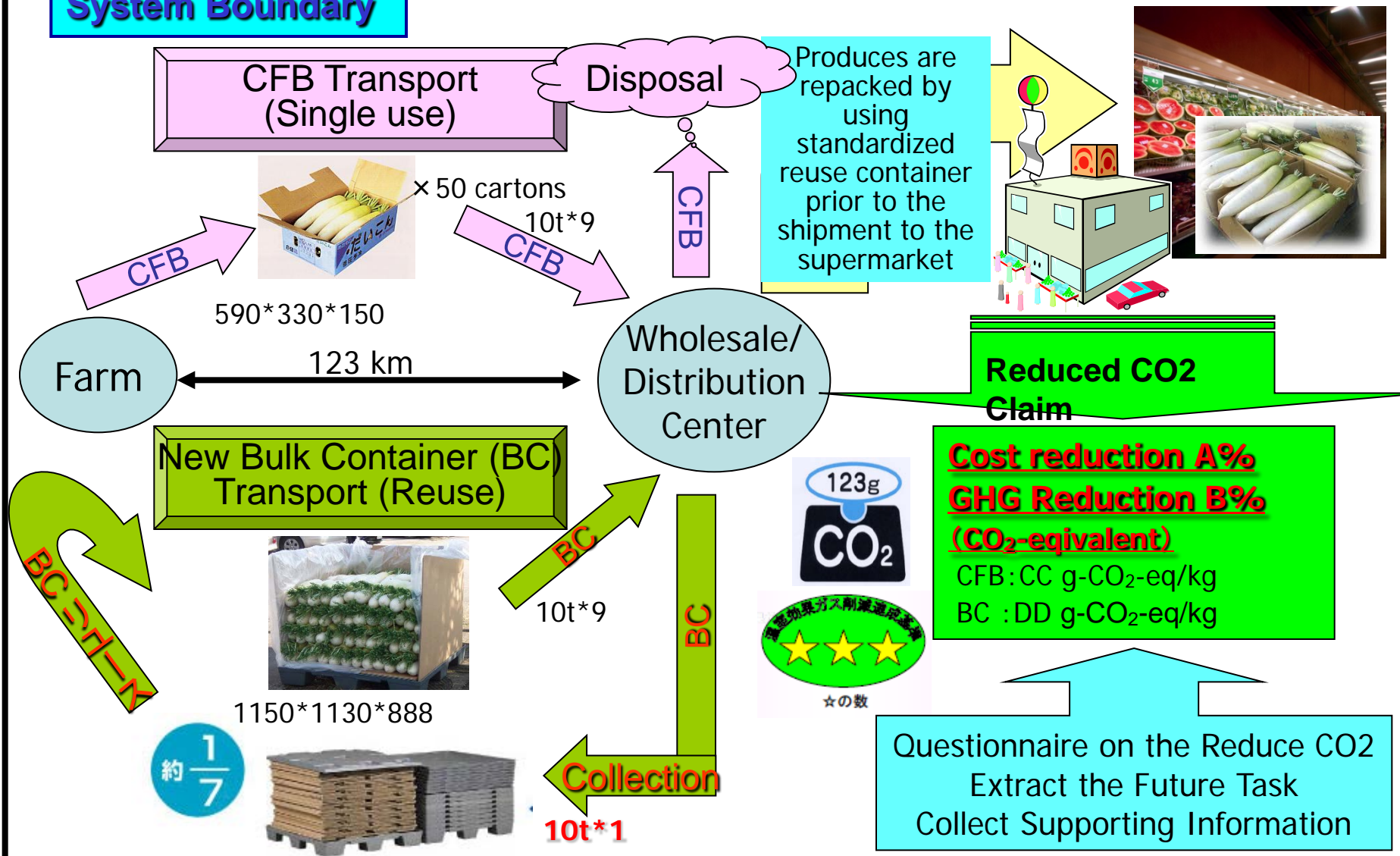
Modify Structure



Optimization of Bulk Container for Fresh Fruits and Vegetable (Structure, size, material, etc.)

3. Demonstration of the Reduction of Cost and CO2 Emission in Retail Store

System Boundary

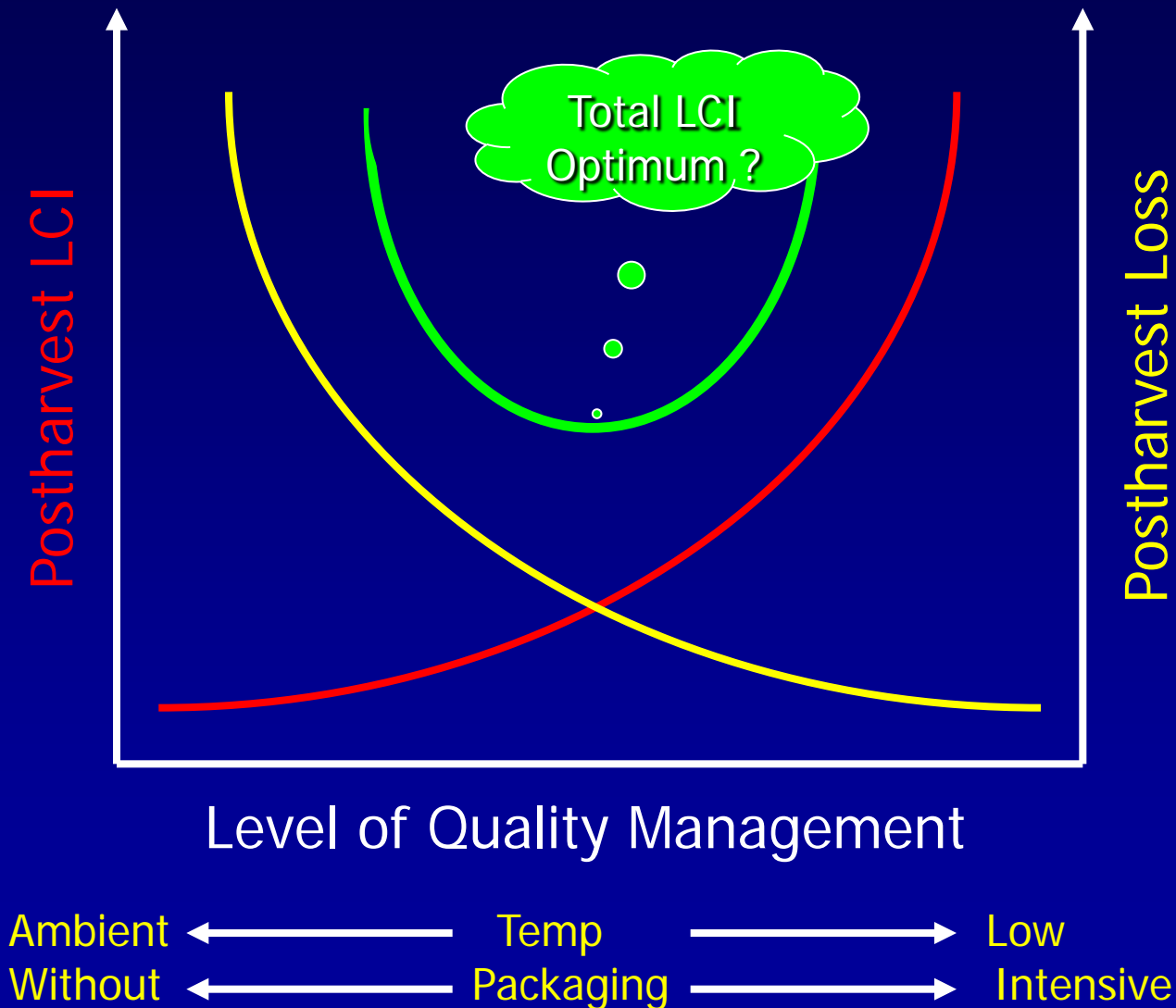


Some factors of product losses due to quality issues (orange boxes) and their impact on lost value (red boxes) in a typical supply chain for vegetables

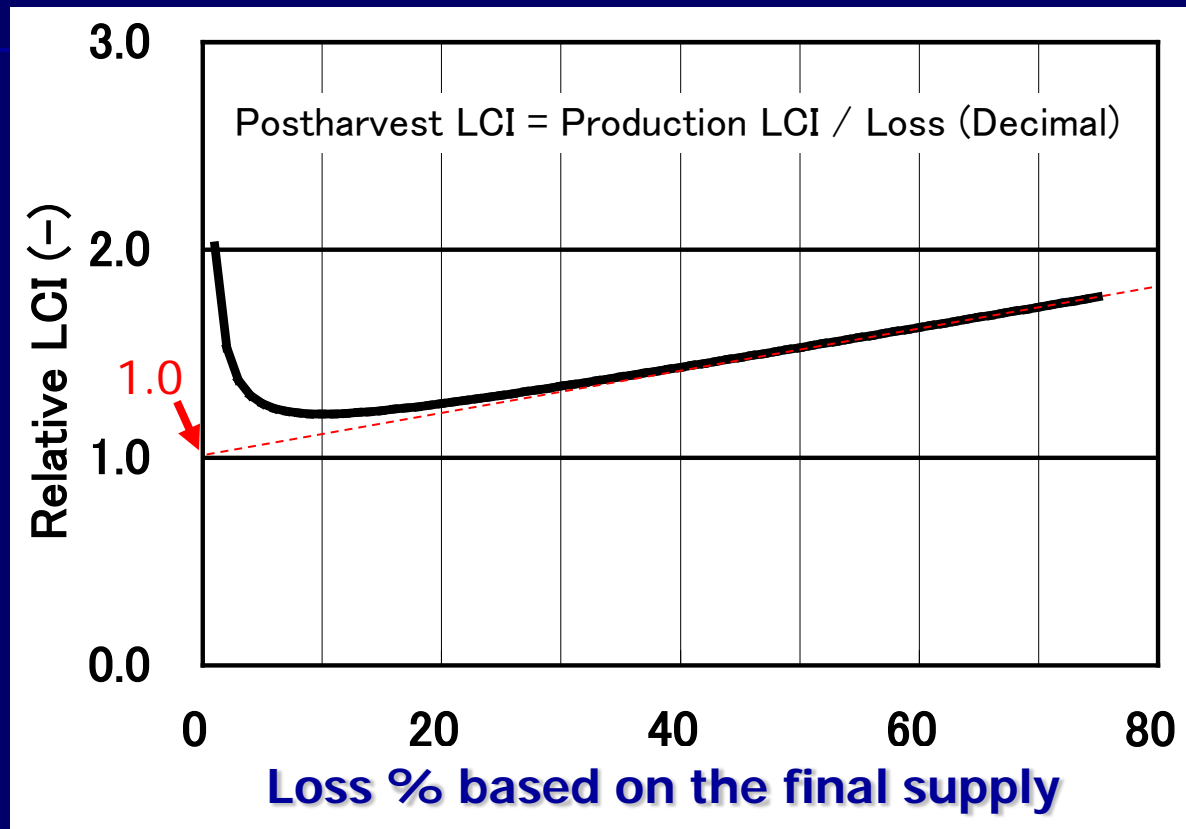


after The Newsletter of Food Chain Intelligence, 3(1), 2010

Effects of the Level of Quality Management on the LCI and Loss



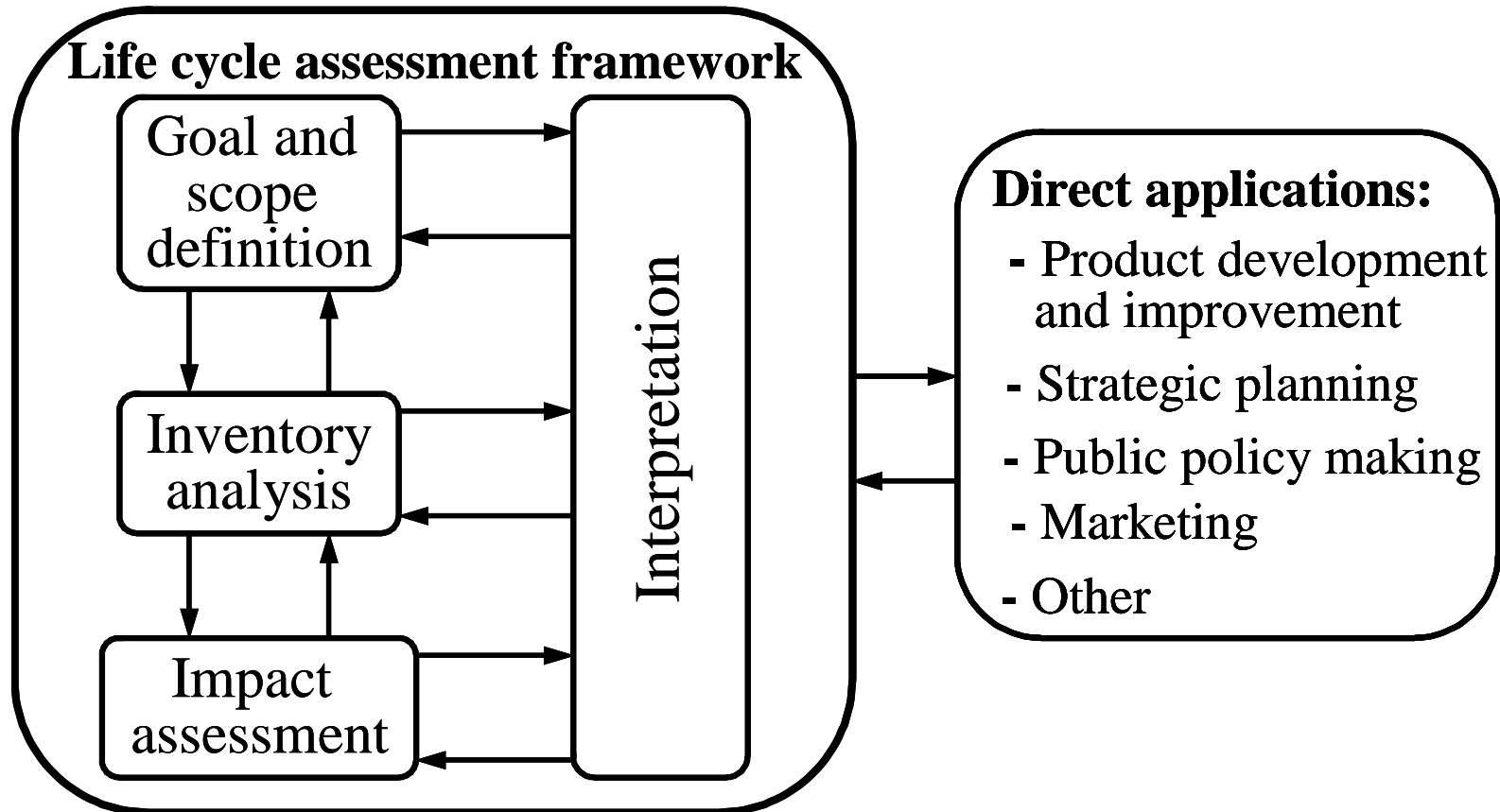
Effect of postharvest process on the LCI of Food by considering the loss of food



Estimation based on the model $Ph = Pr / L$
Postharvest LCI (Ph) 、 Production LCI (Pr) 、 Loss value (L, %)

after Roy et al, 2009

LCA can play an important role



Overview of the LCA process (ISO, 2006)

**Thank you very much for
your kind attention!**