Post-harvest Technologies

Thinking in the way of global agricultural sciences

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Outline

1. What is post-harvest?
2. Post-harvest losses
3. Refrigeration and cold chain development
4. Drying of value-added foods
5. Advanced and appropriate technologies
6. Significance of threshing by farmers in rice distribution
7. Context of modernization
8. Closing Remarks: Post-harvest technology and global agricultural sciences

Post-harvest: Words have wings.

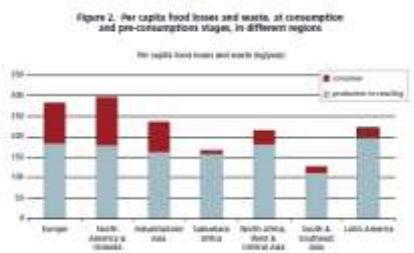
- Literal meaning: “after harvesting”
- Post-harvest does NOT mean agricultural chemicals and pesticides.
- Misuse by Japanese mass media
- *"Our words have wings, but fly not where we would."* *(George Eliot, English novelist, 1819-80)*

Post-harvest process

- Different from crop cultivation (pre-harvest process), post-harvest process is a purely artificial process.
- Post-harvest process consists of:
  1) technological processing
  2) commercial distribution
  (non-technological process)
- Post-harvest process aims at improving labor productivity and product quality.

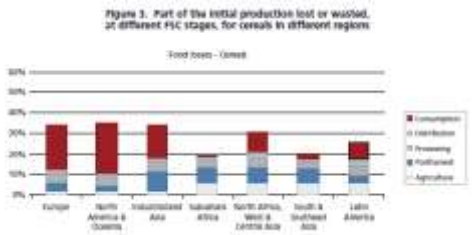
2. Post-harvest losses

Global food losses and food waste



http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

Food losses - cereals



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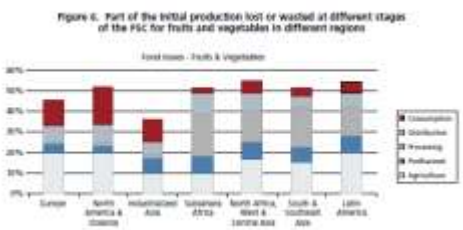
Food losses – fruits and vegetables



http://www.fao.org/docrep/014/mb060e/mb060e00.pdf

Refrigeration requirements and losses due to lack of refrigeration

	World population	Developed countries	Developing countries
Population in 2009 (billion inhabitants)	6.83	1.23	5.6
Refrigerated storage capacity (m^3/1000 inhabitants)	52	200	19
Number of domestic refrigerators (/1000 inhabitants)	172	627	70
Food losses (all products) (%)	25	10	28
Losses of fruit and vegetables (%)	35	15	40
Loss of perishable foods through a lack of refrigeration (%)	20	9	23

Higher energy consumption

Higher post-harvest loss

James et al. (2010). *Food Research International* 43, 1944–1956.

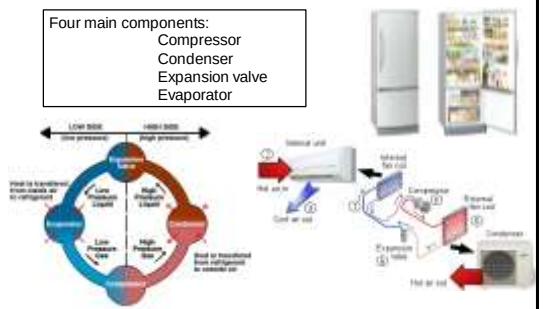
3. Refrigeration and cold chain development

Refrigeration and cooling

- Cooling is a fundamental operation in food processing and preservation.
- Maintaining temperatures lower than ambient inside a system requires both the removal of heat and the prevention of incursion of heat through the system's boundaries.
- Refrigeration systems must be sized to handle the refrigeration load, the rate of heat removal from a system necessary to maintain the temperature.

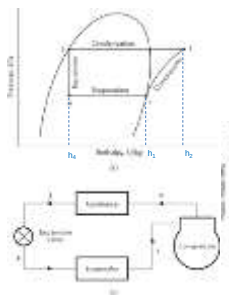
Refrigeration cycle of mechanical refrigeration system

Four main components:
- Compressor
- Condenser
- Expansion valve
- Evaporator

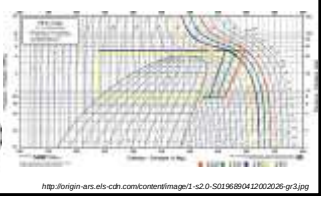


http://www.swtc.edu/Ag_Power/air_conditioning/lecture/theory.gif http://www.airimprove.ltd.uk/images/How-air-con-works-Small.png

Pressure-enthalpy chart and coefficient of performance (COP)



Refrigeration effect: $q_e = h_1 - h_4$ [kJ/kg]
Work required: $q_w = h_2 - h_1$ [kJ/kg]
COP (Coefficient of Performance):
$COP = q_e / q_w = (h_1 - h_4) / (h_2 - h_1)$



http://origin-ars.els-cdn.com/content/image/1-s2.0-S0196890412002026-gr3.jpg

Respiration of fresh produce

- Fresh produce is still alive after harvest.
- Respiration of Fresh Produce:
  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 674$ cal
- Respiration rate (Cumulative amount of CO_2 emission per time per kg product)
- Factors affecting respiration: temperature, humidity, gas concentration, vibration, etc.)

Q10 (Respiratory quotient) and effect of temperature on deterioration rate of fresh produce

Table 1. Effect of temperature on deterioration rate of a non-chilling sensitive commodity

Temperature (°C)	Assumed Q10*	Relative velocity of deterioration	Relative postharvest life	Loss per day (%)
0	----	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	2.0	15.0	7	14
40	1.5	22.5	4	25

*Q_{10} = Rate of deterioration at temperature T + 10°C / Rate of deterioration at T

http://ucce.ucdavis.edu/files/datastore/234-2207.pdf

Cold chain development in Japan

- Low-temperature food supply chain
  - Cooling: 5 to 10 °C
  - Chilled: -5 to 5 °C
  - Frozen: no more than -18°C
- "Recommendation on Modernization of Food Distribution System for Systematic Improvement of Dietary Habits" (in 1965, Resources Council, Science and Technology Agency)
- The above recommendation is usually called "Cold Chain Recommendation".
- Cold chain development resulted in the growth of frozen food industry.

Numbers of Pre-cooling Facilities

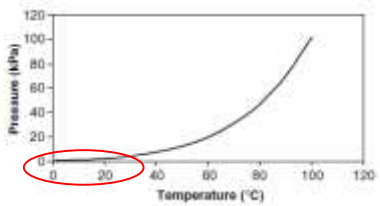
Cooling method	~ 1965	1966 ~ 70	1971 ~ 75	1976 ~ 80	1981 ~ 85	1986 ~ 90
Air cooling	1	22	155	306	360	498
Forced air cooling				35	318	408
Vacuum cooling			6	63	81	163

R&D stage by 5-year grant National research project

Industrial commercialization stage

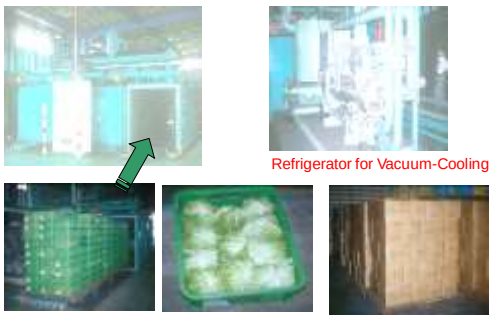
- Chain development led to the drastic increase in the numbers of pre-cooling facilities.

Relationship between Saturated Vapor Pressure and Saturated Temperature



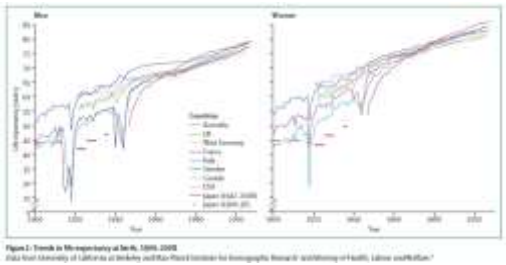
Sun & Zheng (2006). Journal of Food Engineering 77, 203-214.

Vacuum Cooling Facility



Refrigerator for Vacuum-Cooling

Trends in life expectancy at birth (1900-2008)



Ikeda et al. (2011). The Lancet, 378(9796), 1094-1105.

Major drivers of sustained extension of Japanese longevity after mid-1960s

- Stroke mortality reduction
- The control blood pressure improved through population-based interventions such as salt reduction campaigns and an increased use of cost-effective health technologies such as antihypertensive drugs under universal health insurance coverage.

Ikeda et al. (2011). The Lancet, 378(9796), 1094-1105.

Socioeconomic indicators related to cold chain in Japan

Year	Dissemination rate (%)	
	Refrigerator	Microwave
1960	10.1	-
1965	51.4	-
1970	89.1	2.1
1975	96.7	15.8
1980	99.1	33.6
1985	98.4	42.8
1990	98.2	69.7
1995	97.8	87.2
2000	98.0	94.0

Cabinet Office (2009)

Socioeconomic indicators related to cold chain in Asia

	A	B	C	D	E	F
India	17.9	16.2	2.0	1,032	1965-66	1,354,146
China	60.1	29.0	58.3	3,735	1972-73	1,214,464
Indonesia	25.1	22.8	7.3	2,329	1970-71	232,517
Malaysia	84.8	37.2	44.3	6,950	1977	27,914
Thailand	87.3	61.0	19.8	3,941	1972-73	68,139
Vietnam	29.9	17.1	4.3	1,068	1965-66	89,029
Phillipine	47.5	29.1	18.4	1,748	1968-69	93,617

A: Dissemination rate of refrigerator in 2009 (%)
B: Dissemination rate of microwave in 2009 (%)
C: Ratio of sales of modern retailing to those of traditional in 2007 (%)
D: GDP per capita in 2009 (US$)
E: Corresponding Year of GDP in Japan
F: Population in 2010 (Thousand people)

Euromonitor (2009)

Cold chain development plan (2010-15) in China

- Post-harvest losses in China are estimated to be 25% in fresh produce, 12% in meat products, and 15% in fishery products.
- Post-harvest loss of fresh produce reaches to 140 million tons per year.
- The cold chain utilization rates in China are still low, 5% in fresh produce, 15% in meat products, and 23% in fishery products.
- Advanced cold chain systems were first introduced in Shanghai.

	Year		Year
Cold chain recommendation	1965	Cold chain development plan	2010
Tokyo Olympic Games	1964	Beijing Olympic Games	2008
Osaka Expo	1970	Shanghai Expo	2010

Central wholesale market in Jakarta, Indonesia

Historical Background of Kramat Jati Central Wholesale Market

- Established in 1974
- Deregulating the supply chain of agricultural products after economic crisis (1997-98)
- Reconstruction project for improving the market facility (since 2002)

Available floor space of the market is limited, while incoming products are still increasing.

Market reconstruction project in Jakarta, Indonesia

No refrigeration systems were introduced in the market, but it's appropriate. (Appropriate technology)

Before (without roof in the aisle)

After (with roof in the aisle)

4. Drying of value-added foods

Drying consumes a lot of heat energy.

Phase diagram of water

Temperature	ºC	0
	K	273
Heat energy required to melt 1 gram of ice [J]		334
Heat energy required to sublime 1 gram of ice [J]		2,836

1 cal = 4.1855 J; 1 W = 1 J/s

Temperature	ºC	0	20	40	60	80	100
	K	273	293	313	333	353	373
Heat energy required to evaporate 1 gram of water [J]		2,502	2,454	2,407	2,359	2,309	2,257

Drying facility of rice

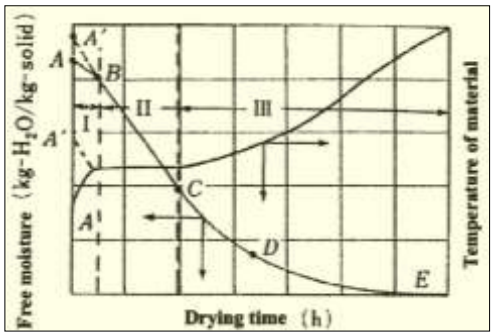
Rice center
(for drying and threshing)

Country elevator
(for drying, threshing and storage)

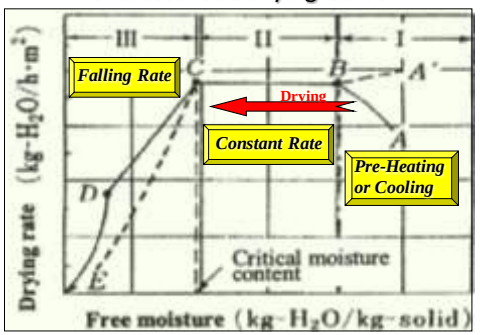
http://www.ja-shizuoka.or.jp/gotemba/images/raisu.jpg

http://upload.wikimedia.org/wikipedia/commons/6/6e/Tsubame_country_elevator.JPG

Experimental Drying Curves of Moisture Content and Temperature



Characteristic Drying Curve

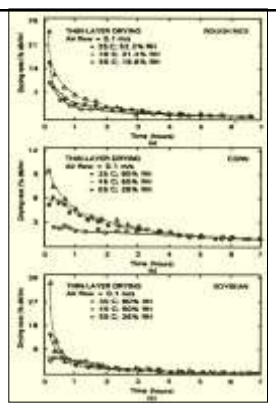


Experimental Drying Rate Curves for

(a) Rough Rice

(b) Corn

(c) Soybean



Characteristic Drying Curves for

(a) Rough Rice

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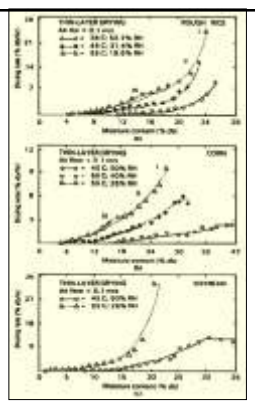


Methods of drying

- Application of hot air (convective or direct drying): Hot-air drying, Spray-drying
- Indirect or contact drying (heating through a hot wall): drum drying, vacuum drying
- Dielectric drying (radiofrequency or microwaves being absorbed inside the material)
- Freeze-drying
- Supercritical drying (superheated steam drying)
- Natural air drying

Production of instant noodles (2007-2011)

Rank	Nation/Region	Year				
		2007	2008	2009	2010	2011
1	China/Hong Kong	45.8	42.5	40.9	42.3	42.5
2	Indonesia	15.0	13.7	13.9	14.4	14.5
3	Japan	5.5	5.1	5.3	5.3	5.5
4	Vietnam	3.9	4.1	4.3	4.8	4.9
5	USA	3.9	4.0	4.1	4.0	4.0

Unit: Billion Packs

- In 2011, 98.2 billion packs of instant noodles were produced in the world.
- Instant noodles drastically changed dietary habits worldwide.

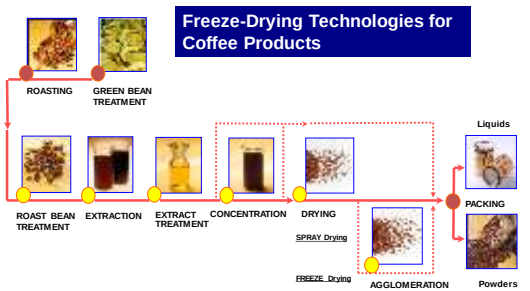
http://www.instantramen.or.jp/data/data02.html

Instant Coffee

Satori Kato, a Japanese chemist, invented soluble instant coffee experimentally by vacuum-drying in 1899.

He presented the invention in 1901 at the Pan-American World Fair.

American inventor George Washington created a mass-produced version of instant coffee in 1906 with Kato's work as a precursor.



Spray-dryer and freeze-dryer

Spray-dryer (pilot scale)

Freeze-dryer (industrial scale)

http://www.sf-machine.com/uploadbigUrea_Formaldehyde_Resin_Spray_Dryer_1_703_1361864950.jpg

5. Advanced and appropriate technologies

Thinking appropriate technology

- Post-harvest technologies provide useful knowledge for large organizations such as governments, companies and agricultural corps.
- Small- and middle-scale farmers cannot invest expensive initial costs, though they understand the usefulness of post-harvest technologies to improve product quality.
- Even if additional values are obtained by post-harvest technologies, the profits are not always distributed to individual farmers.

Politically-sensitive post-harvest technologies

- Post-harvest technologies are strongly related to agricultural, industrial and market policies.
- These political issues are linked with vested interests of multiple stakeholders.
- In international development assistance, post-harvest technology projects are often planned as purely technological projects in order to avoid interference in the domestic affairs.

Diplomatic expressions in project evaluation of development assistance

(Diplomatically)	moderate success
(Honestly)	failure
(Diplomatically)	partly succeeded
(Honestly)	completely failed

JICA's AP4 Project in IPB, Indonesia

- The Agricultural Products Processing Pilot Plant (AP4) Project was implemented by JICA in Bogor Agricultural University (IPB; *Institut Pertanian Bogor*) during 1977-84.
- Post-harvest technology transfer was intended in the project.
- Faculty of Agricultural Engineering in IPB was the main counterpart organization in implementing the project.
- Ex-president Suharto visited the opening ceremony of AP4 on September 7, 1981.
- Many post-harvest processing pilot plants were installed by JICA's equipment provision.
- Many Japanese professors and lecturers were dispatched to IPB.

Outputs and outcomes of AP4 project

- Outputs: moderate success
- Outcomes: The goals of subsequent projects were shifted to the developments of IPB as a higher educational institute.
- AP4 project was implemented as post-harvest technology transfer project in the purely technological way, and that is one of the main reasons why the project didn't work.
- The department in charge of AP4 project in JICA was agricultural technology development, while that in Indonesia was higher education in the Ministry of Education and Culture. (Mismatched)

6. Significance of threshing by farmers in rice distribution

Rice with chaff and brown rice

Rice with chaff Brown rice

Japan's unique distribution of brown rice and its social significance

- In Japan, farmers thresh rice by themselves for selling brown rice as a commodity.
- In other countries, rice mills thresh rice.

This seemingly-slight difference was one of the significant factors influencing farmer's social status and technological progress as well as the evolution of modern industry.

Purely technological point of view for distribution of 'rice with chaff' and 'brown rice'

1. Brown rice has to be packaged before transportation and storage and it results in additional costs.
2. Compared to rice with chaff, brown rice is more easily damaged by insects, birds, mice, high humidity, pollution and so forth, and the damages are critical and irrecoverable.
3. Initial costs of warehouses for brown rice are relatively more expensive than those for rice with chaff, and it results in additional costs.
4. Brown rice has faster quality deterioration and shorter shelf life than rice with chaff.

→ *Brown rice distribution has few benefits from the purely technological point of view.*

Significance of farmer's threshing (1)

Since the quality of brown rice was more easily and objectively evaluated than that of rice with chaff, farmers got a fair price for it according to the quality.

↓

Fair quality evaluation induced the improvement of rice quality by farmers.

Significance of farmer's threshing (2)

Post-harvest treatment has a strong correlation with rice quality, and the utilization of machines and devices is more advantageous.

↓

Farmers acquired knowledge on counting and engineering through improving post-harvest machineries.

↓

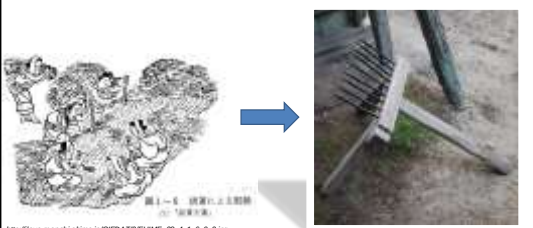
Other agricultural processing and small rural industry were also promoted.

Terakoya education for farmers in the *Edo* Period

- *Terakoya* education: Reading, writing and counting with the abacus (*soroban*)
- Several tens of percent's of the population in Japan were educated by *Terakoya* in the 18th Century.
- Why did so many people want to get educated?
- For example, farmers required the knowledge to calculate the amount of rice paid as a tax.

http://en.wikipedia.org/wiki/File:Terakoya_for_girls.jpg

Senba-koki (Japanese old threshing machine)



http://ilove.manabi-ehime.jp/GIFDAT/2/EHIME_38_4_1_6_0_2.jpg

http://upload.wikimedia.org/wikipedia/commons/4/47/Japanese_old_threshing_machine%2CSenba-koki%2CKatori-city%2CJapan.JPG

Threshing technology was greatly improved; however, this improvement deprived widows of their jobs. That is why Senba-koki has another name of 'Goke-taoshi (後家倒し)'

Significance of farmer's threshing (3)

Since the minimum economic scale of newly developed post-harvest machineries often exceeded Japanese small farmers' individual economic scale, collaborations among farmers were promoted and enhanced.

↓

Cooperative marketing was also promoted by farmers.

Agricultural cooperatives were immediately founded all through Japan just after the world war II.

Rice mills in Indonesia after 1960s

- There are limited numbers of large western rice mills operated by the Chinese businessmen in Indonesia.
- Less than 10% of the total rice production in Java was processed in rice mills.
- Suharto regime (1968-98) allowed purely Indonesian people to establish rice mills easily so that rural economy can be *Indonesianized*.
- *Rapid increase in the numbers of rice mills led to the decrease in traditional jobs of marginalized people.*

Shifting from *ani-ani* to sickles

Rice harvesting by ani-ani

http://medias.photodeck.com/4503ca20-87ae-11e0-bafd-cd77b8a85cf3/7960_14v2_Ani-ani_uxga.jpg

Rice harvesting by sickles

http://farm1.staticflickr.com/9/15521729_d7407d81f9_z.jpg?zz=1

Shifting from ani-ani to sickles improved labor productivity; however, this improvement deprived marginalized people of their jobs.

Meanings of technological and social changes

- Conventional *ani-ani* harvesting allowed everyone to join and get a certain amount of harvested products as rewards.
- In harvesting by sickles, limited numbers of employees were hired and paid in kind or by cash.
- Harvesting by sickles: high-efficiency compared to *ani-ani*
- Diffusion of harvesting by sickles triggered rapid collapse of mutual assistances in rural Indonesia, and it resulted in heavy damage on marginalized people such as small and landless peasants.
- It's true that post-harvest losses were reduced, but …

Rice post-harvest processing and distribution in Thailand in late 1970s

- Rice marketing and processing are made by private parties.
- Technology employed by custom mills has developed as the result of their competition.
- Commercial mills, however, are stagnant in the technical development. The reason might be ascribed to the fact that rice merchants are commercial profit-oriented.
- Since they often work as money-lenders and collect paddy in advantageous terms, they are sometimes hated and prone to be scapegoats on social turmoil.
- This leads to vicious circle to make them concentrate on commercial transaction than processing.
- If paddy price was paid to farmers in proportion to the quality, not only farmers' incentives for quality improvement formed but rice merchant's social status can also be established.

7. Context of modernization

Modernization is equivalent to industrialization:

- Principal roles of commercial company corporations -

- After all, the difference between developed and developing countries is the presence of strong business companies and corporations.
- People in rural villages that are not involved in a market economy enjoy self-sufficient life.
- Companies can do nothing to develop in self-sufficient villages. They are not required as well.
- Companies require the change of self-sufficient rural life for their development.

Safety net in the rural community

- Safety net: Preventive actions and pre-existing resources to deal with the crisis of individuals and societies.
- Mutual assistance and common natural resources are the basic safety-net in the rural community.
- Since the safety net as the stock in the rural community is hard to be seen, many people fail to find its decrease.

Changing process of rural community

- The emergence of business companies in the rural community promotes a market economy and the changes of lifestyles as well as mode of production.
- Subsequently the two traditional safety-nets, mutual assistance and natural resources, start declining.
- Marginalized people face with the crisis of poverty due to the loss of the safety net when something happens.

Context of modernization

- Together with small incomes and job opportunities, modernization is first introduced from the outer world into the whole nations as well as small natural villages.
- Unless the society can supplement the collapse of safety net with something alternative, marginalized people are made to pay the price for the change.
- Context of modernization: the main framework of development assistance

8. Closing remarks: Post-harvest technology and global agricultural sciences

Post-harvest technologies and global agricultural sciences

- How can you facilitate participatory rural development?
- Can you define ‘poverty’ and ‘non-poverty’?
- Is the introduction of post-harvest technologies really effective to facilitate participatory rural development?
- How can you implement post-harvest technology transfer projects without considering socioeconomic conditions of farmers in the project site?

Global agricultural sciences include the questions above.

Closing Remarks (1)

1. Post-harvest process is a purely artificial process, consisting of technological processing and commercial distribution, and aims at improving labor productivity and product quality.
2. As national economic status grows, the main source of food losses shifts from post-harvest processing stage to consumption stage.
3. Refrigeration and cold chain technologies ensure long-shelf life and extending market of perishable products, but socioeconomic conditions of each nation determines whether these technologies are appropriate or too advanced.

Closing Remarks (2)

4. Advanced refrigeration and drying technologies produced new kinds of processed foods such as frozen foods and freeze-dried foods.
5. Post-harvest technologies are politically-sensitive and cross-sectorial. Nevertheless, post-harvest technology transfer projects were often implemented from the purely technological point of view.
6. Japan's brown rice distribution played socially-significant roles in farmer's capacity building by themselves.
7. The meanings of introducing post-harvest technologies and subsequent social changes can be well explained by using the context of modernization.

Assignment

- Choose one question you answer from the following two questions:

1) If Japan's rice distribution system was rice-with-chaff-based, not brown-rice-based, how do you think would be Japan's history going?
2) How should you determine the most appropriate post-harvest technology?

- Answer the question you chose in Japanese or in English.
- The minimum length of the report is 400 characters in Japanese and 200 words in English.
- Deadline: July 12 (Fri), 2013

References (in Japanese)

- 古賀康正 (1989) 農業機械技術者による収穫後処理技術のための技術協力の可能性, 農業機械学会誌第51巻第2号, pp.1-7
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http://postharvest.ucdavis.edu/libraries/publications/