フィリピン共和国
科 学 技 術 省

フィリピン共和国
地場産品競争力強化のための
包装技術向上プロジェクト

＜技術協力成果品(2)＞

技術ガイドライン

平成 29 年 3 月
(2017 年)

独立行政法人
国際協力機構（JICA）

ユニコ インターナショナル株式会社

目 次

1　ガイドライン

Part 1: Smoked Fish (Ver. 5.0)

1.1 Current Practice and Needs for Improved Post-harvest Handling and Packaging Technologies

(1) General feature of smoked fish

"Smoked" fish is presumed to have the following common features in general:

- Good flavor with smoking
- Better preservative quality

In the past, the preservative quality was the main feature of smoked fish, but nowadays, smell and good flavor with smoking is considered as the main feature of smoked fish as a high value product.

(2) Current processing and distribution practice

Table 1-1-1 Current Processing and Distribution Practice of Smoked Fish

Current practice of packaging			Remarks
Procurement of raw material fish and inbound transport of the fish		Styrofoam box with ice	To keep freshness of the fish
Processing		- Cleaning and deboning *) - Heating in brine - Drying and smoking - Cooling and maturing **)	*) Preparation of fish for processing **) To let the flavor penetrate and settle
Outbound transport and distribution of the product	Individual packaging	1) No pre-purchase packaging	
		2) Tray & wrap	For improved visual presentation, protection from mechanical damage, and for self-service selling
		3) Vacuum-packaging	For improved visual presentation and protection from mechanical damage
	Transport packaging	1) (Reused) Corrugated fiberboard box	Over stuffing of the product in the box causes damages on the product
		2) Basket / Crate (returnable container)	

Source: Prepared based on the results from field survey conducted in April 2013 in Bataan

Cleaning and deboning of milk fish

Heating the fish in brine

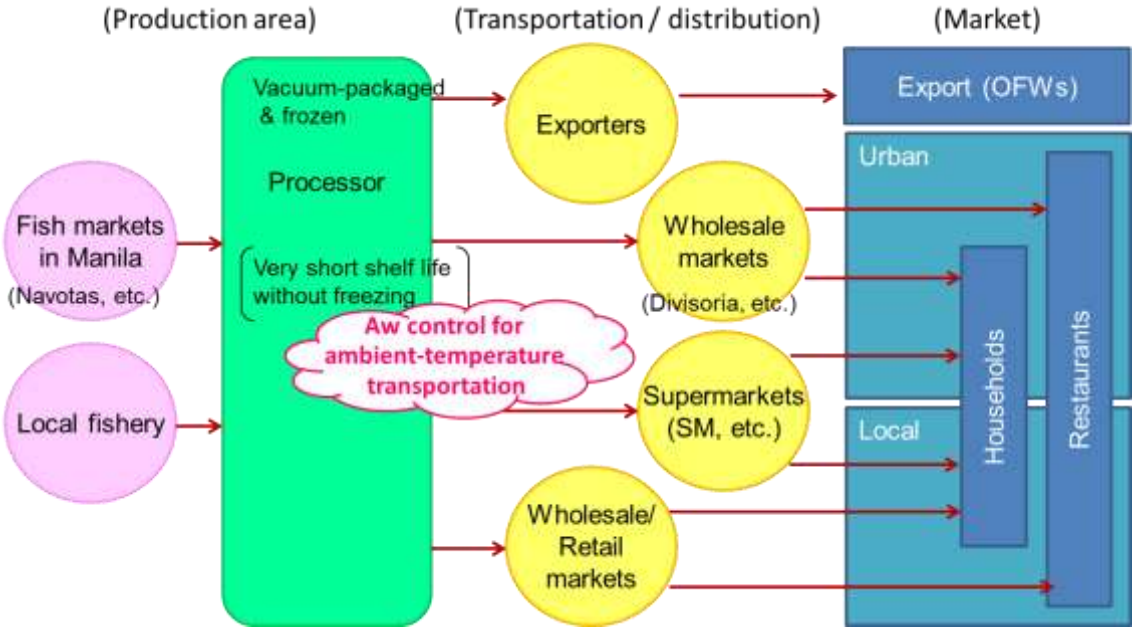
Smoking the fish in small smokers

Put the smoked fish in ON/PE pouch

Vacuum-packaging

Final products

(3) Distribution of smoked fish and emerging needs (case of Bataan)



Source: Prepared based on interviews conducted in April 2013 with smoked fish processors in Bataan

Figure 1-1-1 Distribution of Smoked Fish and Emerging Needs

It has been observed in other production areas like Cavite, Batangas and Calbayog that vacuum-packaging and freezing practices are required by buyers not only for overseas but also for domestic markets.

(4) Issues and needs of improvement in processing and distribution of smoked fish

Currently smoked fish processors in Bataan procure raw materials mainly from fish markets in Manila, while some raw fish can be obtained from local fishermen.

Regular smoked fish products can be kept for only 3-5 days at ambient temperature. Since refrigerated storage and cold chain distribution are not yet generally available in the Philippines, the shelf life is very short and hence sales opportunities for the product are limited. Frozen storage and cold chain distribution are the countermeasures to the limited shelf life of the product. The energy cost, however, has been a burden to processors and distributors. The current issues observed on smoked fish distribution are explained below.

1) In the case of distribution without freezing:

- Short shelf life (markets are limited to those of short distance only)
- Risk of deterioration of the quality in a short time in the distribution process (bacterial spoilage and fat oxidation)
- Mechanical damages on the product during transportation due to over stuffing in (reused) carton box

2) In the case of distribution with freezing:

- High cost for freezing
- High cost for cold chain distribution
- Unreliable/unstable cold chain, resulting in risk of quality deterioration in the distribution process
- Need for cooking before serving (The product is not ready to eat.)

Considering the currently available physical distribution system and high energy cost for freezing and cold chain distribution, there is a need to develop smoked fish products of long shelf life which can be distributed at ambient temperature.

Reused corrugated fiberboard boxes and newspaper, while being the most common packaging material for transport in the Philippines, cause problems on the product quality. The problems include mechanical damage due to insufficient strength of reused boxes and/or migration of foreign substances from packaging materials like newspaper. However, the most commonly observed mechanical damage of smoked fish seems to be caused by over-stuffing of the product in a box, since distributors or buyers request to pack as much of the product as possible in order to save the packaging cost.

The current practice of packaging and needs for packaging development of smoked fish are shown in Table 1-1-2.

Table 1-1-2 Current Practices and Needs for Packaging Development

Current practice		Needs for packaging development
Frozen smoked fish: - Vacuum-packaging using a nylon-laminated film pouch - Frozen storage and transportation of the packaged smoked fish	For long-distance transport to urban or overseas markets High energy cost for freezing, frozen storage, and frozen distribution.	Extend the shelf life of packaged smoked fish product under refrigerated or ambient conditions in order to address: 1) High energy cost associated with frozen smoked fish 2) Limited availability of cold storage and distribution system 3) Short shelf life of existing products under refrigerated or ambient condition that restricts wider distribution of the products
Non-frozen smoked fish: - Vacuum-packaging, tray & wrap packaging, or without any individual packaging of smoked fish - Refrigerated or ambient-temperature storage and transportation of the product	Immediate consumption after purchase	

Source: Prepared based on interviews conducted in April 2013 with smoked fish processors in Bataan

1.2 Freshness Preservation of Intermediate Moisture Foods (IMF)

Foods are categorized into high moisture foods (HMF), intermediate moisture foods (IMF), and dried foods in terms of their water activity (Aw). Water activity is the barometer of free water content of food, and not directly related with moisture content of food. The traditional smoked fish in the Philippines is categorized as the HMF. Table 1-2-1 shows some representative foods in in each category.

Table 1-2-1 Classification Table of Food by Water Activity

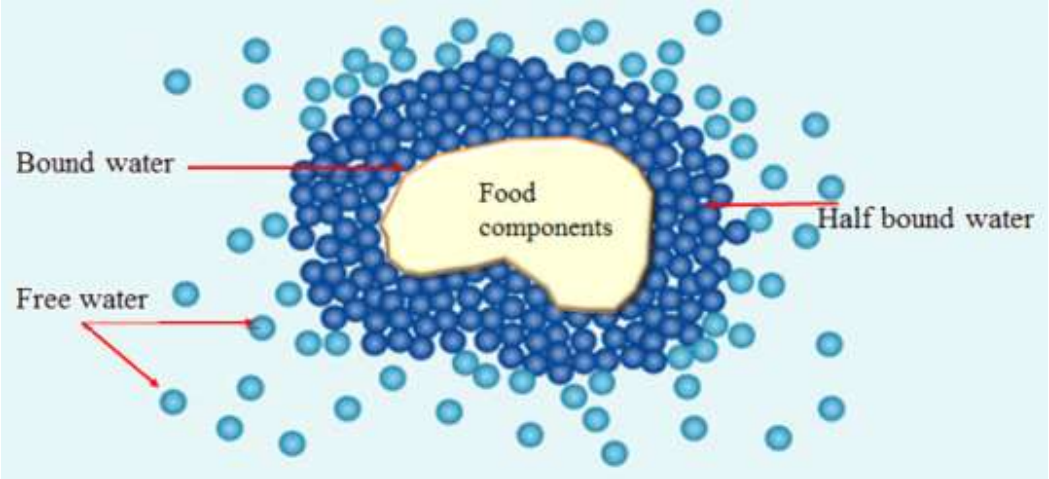
Dry Food (DF)	Intermediate Moisture Food (IMF)	High Moisture Food (HMF)
Aw. 0.65-0.00	Aw. 0.90-0.65	Aw. 1.00-0.90
• Cookie, Rice cracker, Dried confectionaries, Deep-fried, Vacuum-dried fruits & vegetables, Potato chips, Popcorn, Snack foods, etc. • Instant dried foods (Instant noodle & soup), Breakfast cereal, Dry fruit, etc. • Dried fishery products, Dried milk, Dried meat, Powdered foods (Instant soup, Skimmed milk, etc.) • Green tea, Black tea, Regular & instant coffee, etc.	• Processed IMF (Salty foods, High sugar foods) • Semi-dried traditional foods (Dry fruits, Dried fish & shrimp, Confectionaries, etc.) • Traditional seasonings (Fish sauce, Soy sauce, Bagoon etc.)	• Fresh foods (Fruit, Vegetable, Meat, Milk, Egg, Fish, Shellfish, Sea weed, etc.) • Daily necessity foods (Fresh noodles, Bread, Pickles, Tofu, etc.) • High moisture processed foods (Ham & sausage, Fruit & vegetable juice, Cakes, Cooked fishes, etc.) • Beverages

Source: Prepared by the JICA Project Team

For preservation of freshness of the smoked fish, understanding of characteristics of the IMF is important.

(1) Water activity (Aw)

Aw (water activity) is the barometer of free water content of foods. Water in food which is not bound to food molecules called free water, can support the growth of bacteria, yeasts and molds (fungi). The term water activity (Aw) refers to only this free water. On the other hand, “Moisture content” means the volume of all the 3 types of water contained in the material (food), which are bound water, half bound water and free water.



Source: Prepared by the JICA Project Team

Figure 1-2-1 Conceptual Image of Free Water

(2) Poisoning bacteria

There are four types of microorganisms, which should be focused in view of food safety, as follows:

i. Spore-forming (heat resistant) bacteria i.e. *Bacillus, Clostridium*
ii. Non Spore-forming bacteria
iii. Molds
iv. Yeasts

The growth of the types of microorganisms and their varieties are limited by the levels of Aw. Spore-forming bacteria have a feature of heat resistance, so that they cannot be killed by heat pasteurization but can be controlled by Aw of lower than 0.90. Spore-forming bacteria can be sterilized by high temperature short time (HTST) or retort sterilization technology. On the other hand, non-spore forming bacteria, molds and yeasts can be killed by heat pasteurization at 85℃ for 30 minutes even though some of them can grow under low Aw. Therefore the growth of all poisonous microorganisms can be thoroughly prevented by both heat pasteurization and Aw control.

Regarding the poisoning bacteria, Table 1-2-2 shows the detail about the Aw level suited for their growth.

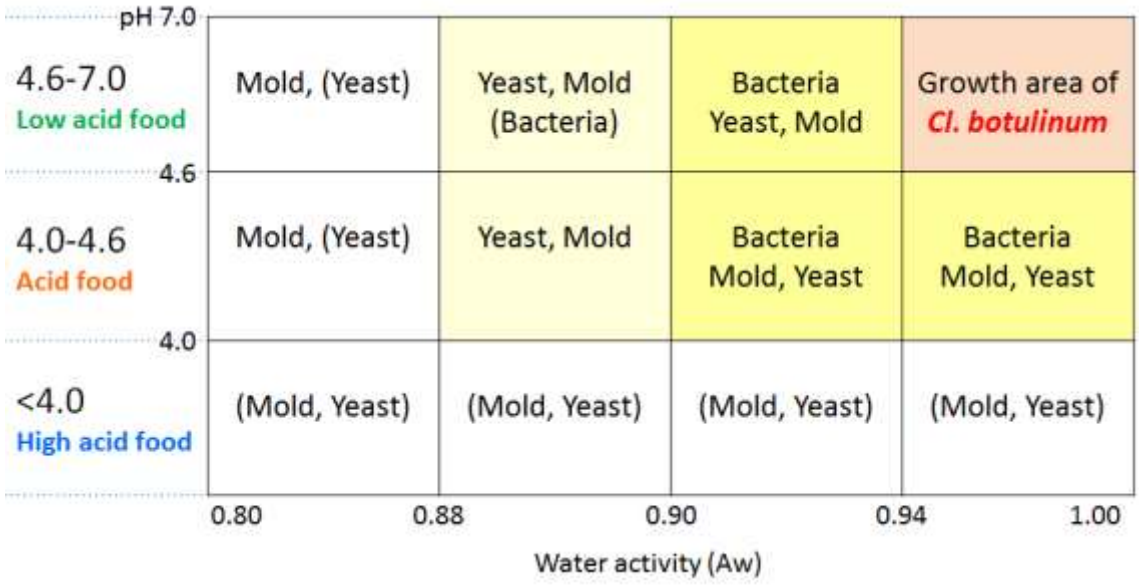
Table 1-2-2 Classification Table of Poisoning Bacteria

	Bacteria	Maximum level of Aw to prevent the bacteria, regulated by:		Infection level	Minimum temperature for growth
		MHLW (Japan)	FDA (USA)		
Spore forming/ heat resistant	*Bacillus cereus* (aerobic)	0.93	0.92	100,000<	10℃<
	Clostridium perfringens (anaerobic)	0.93	0.93	100,000<	12℃<
	Clostridium botulinum Proteolytic (anaerobic)	0.94	0.935	100,000<	10℃<
	Clostridium botulinum Non-proteolytic (ditto)	0.97	0.97	100,000<	10℃<
Non-Spore forming	*Staphylococcus aureus*	0.86	0.83	100,000<	6.6℃<
	Vibrio parahaemolyticus	0.94	0.94	10,000<	10℃<
	Salmonella	0.94	0.94	100-1,000	7℃<
	Listeria monocytogenes	0.90	0.92		4℃<
	Campylobacter jejuni	0.98	0.98	100>	5℃<
	enterohemorrhagic Escherichia coli	0.95	0.95	100>	7℃<

Note: MHLW: Ministry of Health, Labor and Welfare in Japan
FDA: Food and Drug Administration in the United States of America
Source: Prepared by Takasuke Ishitani, figures based on published guidelines and literatures as of 2015.

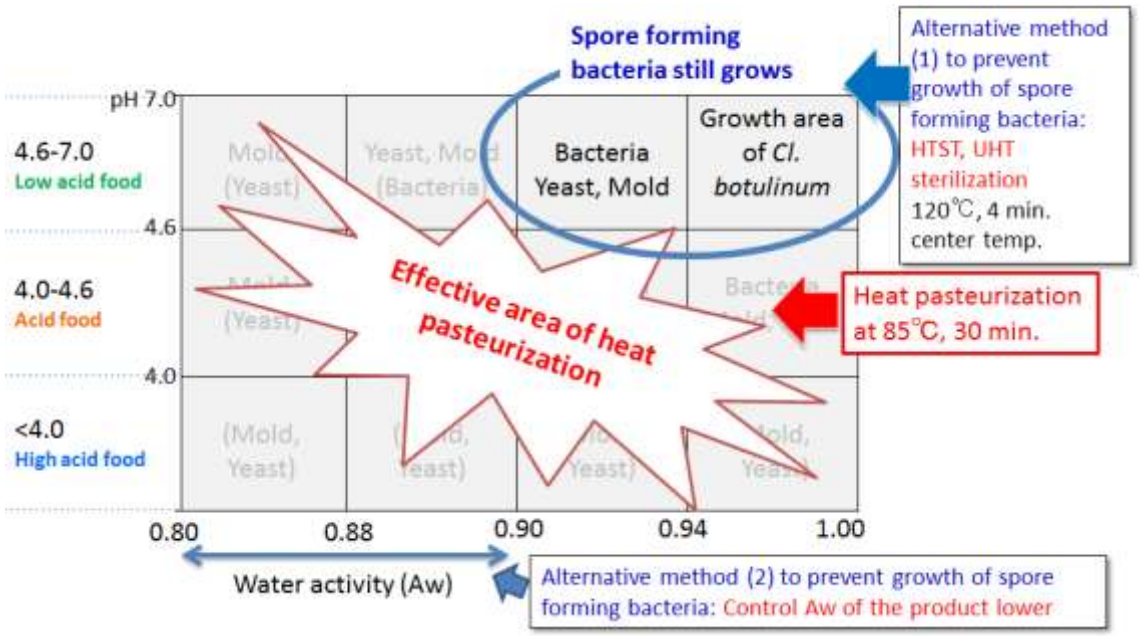
In addition, pH is also an important factor in terms of growth condition as presented in the figure below. However, decreasing acidity is not always good for maintaining good texture and taste. Aw control is inevitable for preserving the quality.

Clostridium botulinum can grow only under the condition of above Aw 0.94 and pH 4.6. Most of the bacteria cannot grow under the condition of below Aw 0.90 and pH 4.6 except *Staphylococcus aureus* (see Table 1-2-2).



Note: Parenthesis indicates that slow growth of the item is observed.
Source: Prepared by the JICA Project Team

Figure 1-2-2 Growth Area of Bacteria, Molds and Yeasts in Terms of Aw and pH



Source: Prepared by the JICA Project Team

Figure 1-2-3 Countermeasures of Growth Area of Bacteria, Molds and Yeasts

(3) Methods for lowering water activity (Aw)

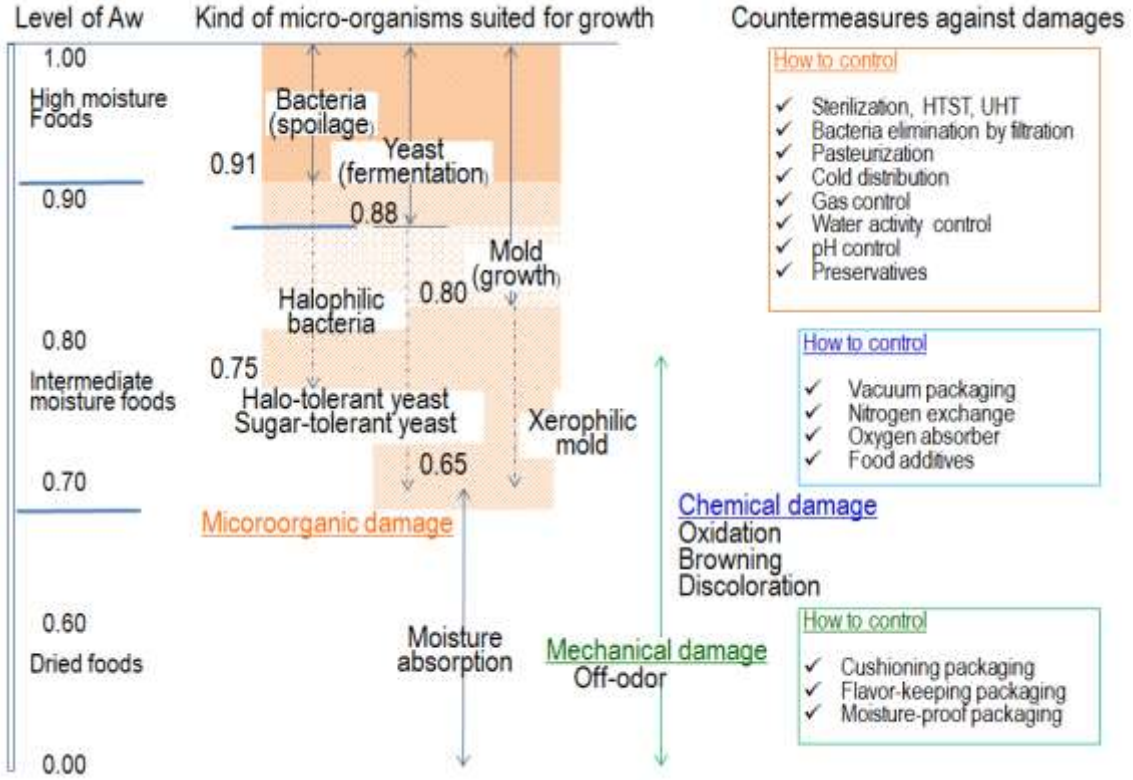
There are some possible methods to be applied to prevent the IMF from growing of the poisoning bacteria as below.

- Addition of NaCl (soy sauce)
- Addition of sugars, amino acids and other solutes (sugar and honey)
- Addition of natural preservatives (sorbate, sugar alcohol, glycine, etc.)
- Cooking with seasoning mixture
- Smoking and drying (removing of the free water of food)

The process of the smoked fish also applies the combination of these methods.

(4) Chemical changes in packaged foods

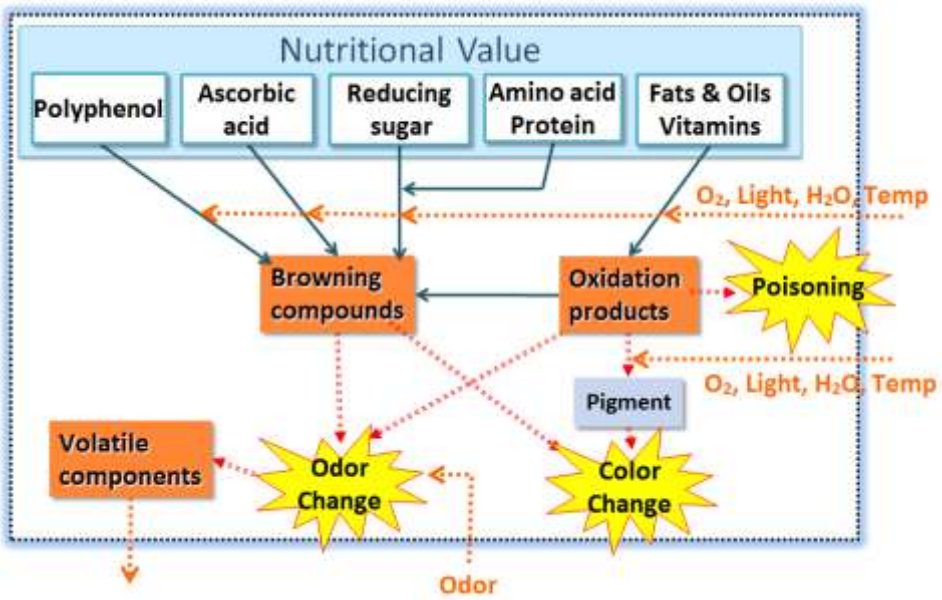
Apart from the micro organic control as explained above, chemical damage and mechanical damage also should be controlled, since those are caused even under lower Aw as presented in Figure 1-2-4.



Source: Takasuke Ishitani et.al, "Syokuhin to Hoso [Food and Packaging for Good Quality and Safety]," 1982.

Figure 1-2-4 Type of Damage and Countermeasures

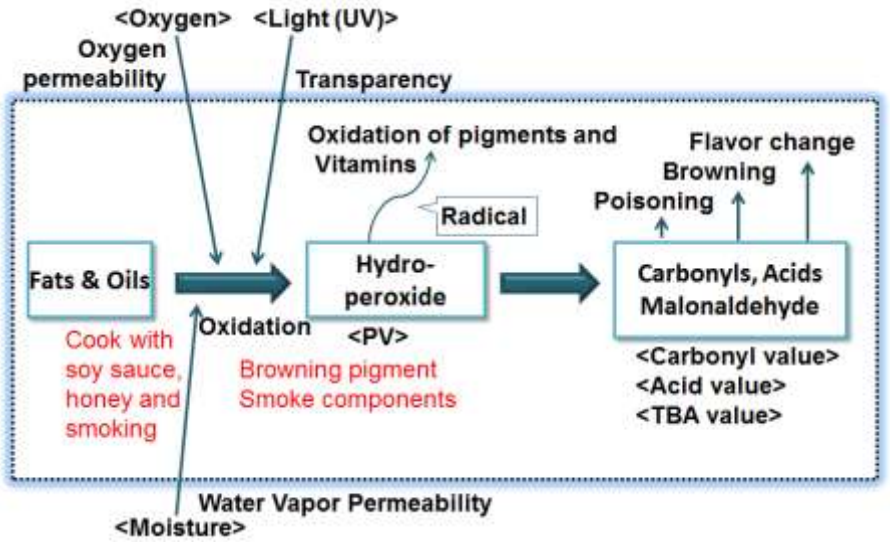
The existence of oxygen, changes in moisture content, and temperature fluctuation affect food quality change, and cause oxidation and browning, which leads color change and off-odor development of foods, as shown in Figure 1-2-5.



Source: Prepared by the JICA Project Team

Figure 1-2-5 Factors Affecting Deterioration of Smoked Fish

As regards the effects of environmental factors like oxygen, light (UV), and moisture (RH) on the oxidation of fats and oils, the figure below shows the mechanism of chemical change of fats and oils that produces chemical substances and causes flavor change, browning and poisoning. In case of smoked fish, chemical components of smoke and browning pigments of soy sauce have anti-oxidation effects to fats and oils in fish.



Source: Prepared by the JICA Project Team

Figure 1-2-6 Factors Affecting Deterioration of Smoked Fish (2)

1.3 Proposed Improvement of Processing Practice and Packaging Development

On the basis of the characteristics of IMF as described above, the development of a smoked fish product which can be distributed without freezing, or even at an ambient temperature, is proposed to meet the needs of smoked fish processors and distributors.

1.3.1 Development of the Smoked Fish Product Which can be Distributed Without Freezing at Ambient Temperature

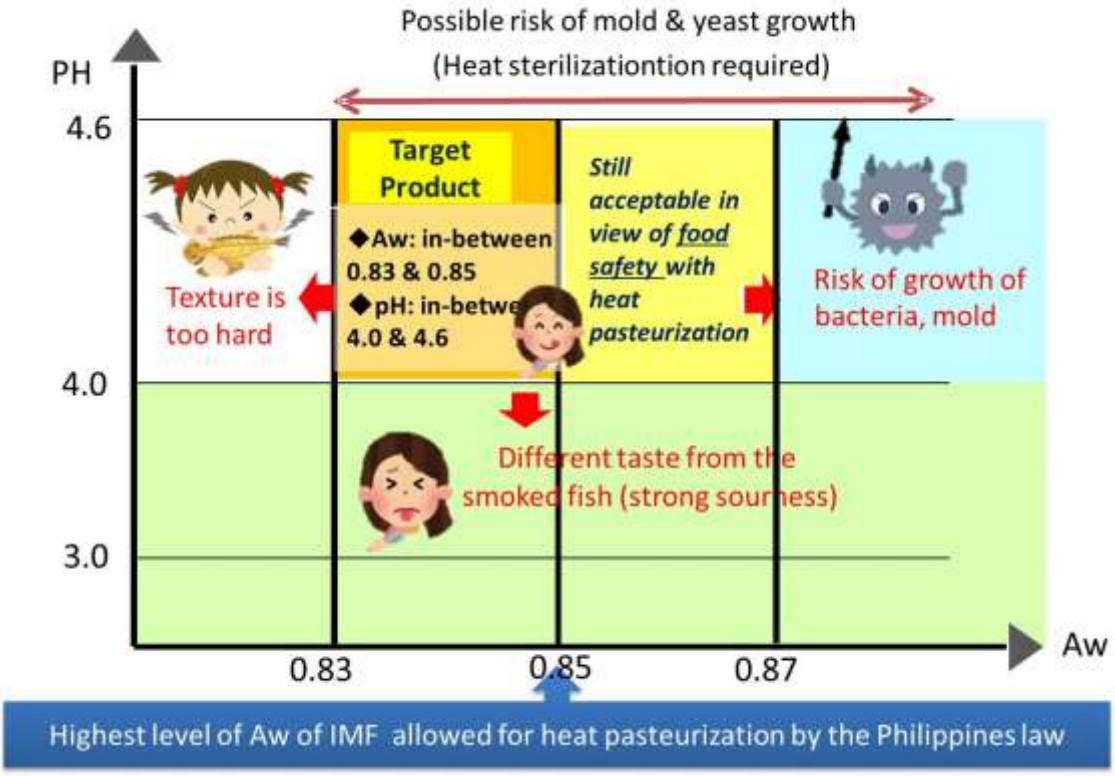
(1) Proposed concepts of the product and the applied packaging technologies

The concept of the proposed product is a smoked fish which can be distributed without freezing, or at ambient temperatures, with longer shelf-life compared with the current products. Main features of the proposed product are:

- ✓ Ready-to-eat product[1]
- ✓ Good flavor and texture as a higher-value product
- ✓ Stable and free from bacterial and fungal growth even at ambient temperature during distribution and storage
- ✓ Stable and free from fat oxidation even at ambient temperature during distribution and storage

As a countermeasure to achieve the feature above, maintaining lower Aw of the product is critical for preventing the growth of spore-forming bacteria. Theoretically spore-forming poisoning bacteria will not grow at the Aw of 0.90 or lower, however statutory the Philippine law requires that Aw be below 0.85 for heat pasteurized packaged foods. In order to make the product soft and less salty, keeping the Aw as close to 0.85 as possible is highly recommend.

[1] In the Philippines, smoked fish is eaten mostly after deep-frying. However, the proposed product aims at a new style of smoked fish which is seasoned and ready to eat.



Source: Prepared by the JICA Project Team

Figure 1-3-1 Target Product in terms of Aw and pH

(2) Proposed process of preparing the product and packaging development

Considering the concept above, the development plan of the proposed smoked fish product is as follows:

1. The fish is processed to the seasoned and smoked product, with **Aw** being maintained between 0.83 and 0.85 at the end of the processes to prevent spore-forming poisoning bacteria
2. The hot-smoked fish is packaged with **high gas-barrier pouches** and vacuum-sealed to prevent fat-oxidization, non-enzymatic browning and off-odor development
3. The packaged smoked fish product is **boil-pasteurized** at the temperature of 85℃ for 30 minutes to prevent non-spore forming bacteria

Table 1-3-1 presents the outline of targets and its measures with indicative values for the proposed smoked fish.

Table 1-3-1 Outline of Targets and Its Measures

Targets	How to achieve the targets	Rationale
Good Flavor and Texture	Maintain Aw at 0.83 or higher	As Aw of the product drops lower than 0.83, the texture becomes harder and the taste more salty.
	Maintain pH at 4.0 or higher	If pH of the product is lower than 4.0, then it tastes sour.
Prevent Quality Deterioration	Vacuum-package using high gas barrier plastic film for individual package	Fat oxidation, non-enzymatic browning, off-odor development occur with presence of oxygen during distribution and storage
Prevent Bacterial Growth	Maintain Aw at 0.85 or lower	Spore forming poisoning bacteria cannot grow on the food below 0.93 Aw (Actually Aw should be lower than 0.85 due to the law of the Philippines)
Kill Bacteria, Yeast and Mold	Conduct of boil pasteurization at 80ºC for 30 minutes or longer	Non-spore forming bacteria, yeasts and molds can be killed by hot water pasteurization at 80ºC or higher for 30 minutes or longer, depending on the thickness of fish.

Source: Prepared by the JICA Project Team

1) Prevention of bacterial growth – by Aw control

Spore-forming poisoning bacteria cannot grow below Aw 0.93 as explained in Table 1-3-1. Aw of the proposed smoked fish product can be controlled by [1] adjusting Aw by the ingredients of seasoning mixture for marinating process, and [2] adjusting the moisture content by drying and smoking.

In the marinating process, the seasoning mixture should be prepared considering the proportion of sodium ion from salt and soy source, and sugar content including honey. The stronger the taste is, the lower the Aw gets. The longer the time is and/or the higher the temperature is for the marinating process, the lower the Aw of the final product gets. In the drying and smoking processes, longer time and/or higher temperature make the Aw of the final product lower. Therefore time and temperature in these processes should be well controlled.

On the other hand, the product which is too salty, too hard and/or too smoky cannot survive in the market. Producers should define a strategic balance considering preference on the product in the target market on one hand, and the capacity or performance of the equipment on the other.

2) Prevention of oxidation - by using high gas barrier film

Fat oxidation, non-enzymatic browning and off-odor development will occur under presence of oxygen during storage and distribution. So, in order to prevent the product from these deteriorations, use of a high barrier pouch (KON) with vacuum sealing is strongly recommended, as one of the critical control points in this production process.

Table 1-3-2 shows the oxygen transmission rate of the three types of film at 25ºC. KON is recommendable since it has the lowest oxygen permeability among the three.

Table 1-3-2 Type of Film and Oxygen Transmission

Type of film	Oxygen transmission rate
KON (PVDC-coated oriented nylon)	10cc/m2/day・atm
ON (oriented nylon)	80cc/m2/day・atm
OPP (oriented polypropylene film)	2000cc/m2/day・atm

Source: Prepared by the JICA Project Team

Table 1-3-3 shows characteristics of some films. For the proposed process of smoked fish, both heat resistance and high gas barrier are necessary. In this point of view, PVDC coated films, SiOx (silica) vaporized PET, Al_2O_3, (alumina) vaporized PET, Aluminum foil laminate meet the requirements. Considering availability in the market and price, VDC coated oriented nylon is most likely.

Table 1-3-3 Properties of Selected Films

Film type	Gas barrier	Heat resistance	Permeability except gas	Remarks
Low density polyethylene	High gas permeability	-	WV barrier	Low price, General-purpose film
Soft polyvinyl chloride	High gas permeability	-	-	Pouch & wrap, General-purpose film
Oriented polypropylene (OPP)	-	-	Low WV permeability	Low price General-purpose film, Transparency
Polystyrene	-	-	Higher WV	For vegetable, Plastic container, Transparency
Polyethylene terephthalate	Middle gas barrier	Heat resistant	Flavor barrier, Transparent,	-
Oriented Nylon (ON)	Middle gas barrier	Heat resistant	High strength,	Transparency
MXD6 (barrier) Nylon	Gas barrier	-	Moisture-proof, High strength for oxygen absorber	-
Polyvinylidene chloride (=PVDC)	High gas barrier	Heat resistant	-	Tube, Wrap and coated films,
PVDC coated ON, PET, OPP films	High gas barrier	Heat resistant	-	-
Ethylene vinyl-alcohol copolymer	High gas barrier	-	Flavor barrier	Multi-layer barrier film and bottle (co-extrusion)
SiOx (silica) vaporized PET Al2O3 (alumina) vaporized PET	High gas barrier	Heat resistant,	Transparent	Expensive
Aluminum vaporized PET (Vacuum Metalized)	Gas barrier	Heat resistant	-	For s nack foods, Shading (no transparency)
Aluminum foil laminate	Perfect high barrier to oxygen	Heat resistant	WV barrier	For retort foods, Expensive, Shading

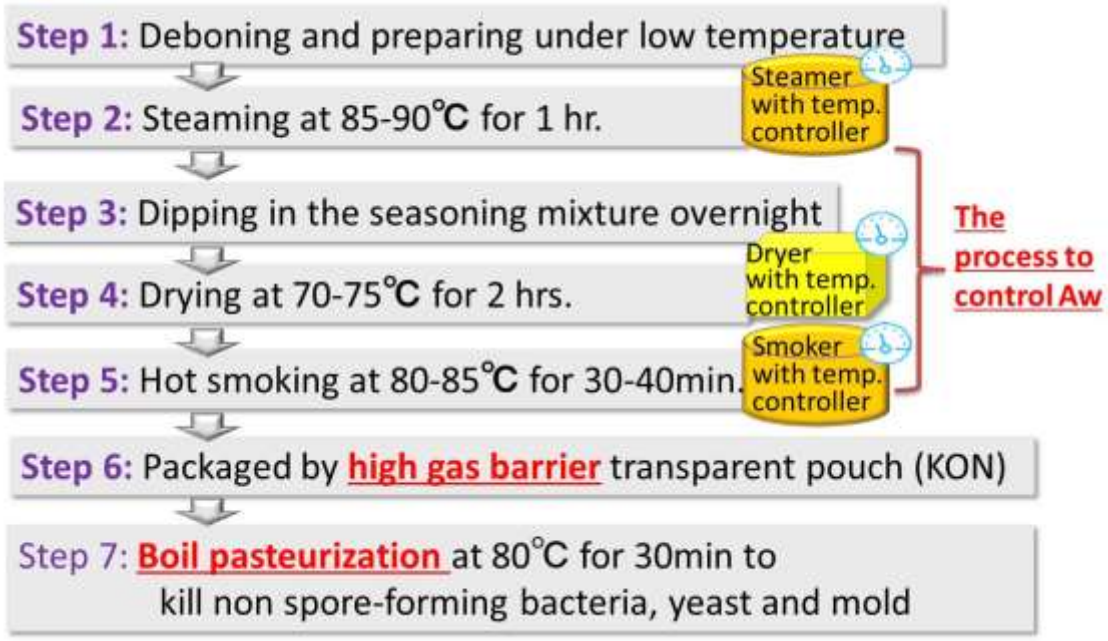
Source: Prepared by the JICA Project Team

3) Prevention of bacterial growth – by heat pasteurization

After vacuum-packaging, the product should be boiled, since non-spore forming bacteria, yeasts and molds which cannot be controlled by Aw, can be killed by heat pasteurization at 80ºC for 30 minutes. KON pouch has enough durability for boil pasteurization.

(3) Detail process of the proposed smoked fish

The proposed flow of processing was verified through the verification trials conducted in PTD. Time and temperature here is based on the assumption that fish is prepared at 100g /piece (fillet) or 250g/whole fish, using the equipment in PTD. Time and temperature should be adjusted according to size or thickness of fish and also capacity/performance of equipment to be used.



Source: Prepared by the JICA Project Team

Figure 1-3-2 Proposed Process of Smoked Fish

Table 1-3-4 Indicative Values on Each Process

Process	Standard operation condition	At the end of the process		Remarks
		Weight	Aw	
1) Deboning and preparing raw fish	Low temperature shorter time	g	0.99	Need hygienic control
2) Steaming	85-90°C, 1 hr.	g	0.99	Steaming helps to marinate well. About 20 % of drip occurs.
3) Dipping in the seasoning mixture	Overnight under ambient	g	0.92 -0. 89	Aw of mixture: 0.62 Increase the weight but lower Aw due to absorbed salt content
4) Drying	70-75ºC, 2hrs and more if necessary	g	0.89 – 0.85	Dry until Aw become 0.85
5) Hot smoking	80-85ºC, 40min	g	0.85 -	To prevent bacterial growth by lowering Aw to give good flavor
6) Vacuum package with high gas barrier film	Barrier level of film O_2 10cc/m^2·24hrs	g	0.85 -	To prevent fat-oxidation, non-enzymatic browning & off-odor development
7) Boil pasteurization	80ºC, 30min	g	0.85 -	To prevent growth of non-spore forming bacteria, yeast & mold

Source: Prepared by the JICA Project Team

In order to ensure the food safety, and at the same time considering the prevailing handling process of raw fish, all workers should understand the importance of clearing the critical points instructed and the meaning of the standardized operation procedure and the needs.

(4) Findings through the development trials

1) Steps 1-5

These steps are important for lowering the Aw of the product to prevent spore-forming poisoning bacteria. At the same time, these processes affect significant influences on the flavor and texture of the product. The following is operational remarks based on the findings through the trials.

【Seasoning mixture】

- The seasoning mixture consists of soy sauce, sugar, salt, honey and sliced ginger. The proposed formulation is 32/48/8/7/5 for 100g of fillet, however it should be defined according to the ingredients actually used. For example, in this formula, soy sauce is a light color type with the Aw of 0.90 and the salt content of 15-16%, made by Marca Piña Co. Ltd.

- For better appearance of the final product, light color soy sauce, white sugar, and honey are used.
- Reusing of the seasoning mixture should be considered from a viewpoint of input saving and cost management. It is not easy to calculate how much of each ingredient should be added but estimation can be made by measuring the Aw, sodium ion content, water content and sensory experiences.

【Dipping in the seasoning mixture】

- All fillets should be evenly soaked in the seasoning mixture. If you use PE bag for dipping, pushing out air when you tie up is important.
- Marinating overnight at ambient temperature leads homogenization to decrease sample variation compared with the case in a few hours soaking in hot water. Moreover, soaking in hot water is not recommended for chemical substances may dissolve from the PE bag.

【Drying】

- Two hours of drying is preferable in case of the dryer at the PTD. After three hours, fillets become too hard.
- Time length for drying depends on the performance of equipment, quantity of fillets and so on.
- Air drying or sun drying without using a dryer is also acceptable on condition that it takes more time.
- Smoker can be used as a dryer by heating with an electric heater or a gas burner without woodchips.

【Smoking】

- Smoking time also depends on the performance of equipment, quantity of fillets, amount of woodchips, and so on.
- By using a gas burner as heat source, water vapor comes up and avoids decreasing Aw. In this case, flame of gas burner should be interrupted by plate using for woodchips.
- Woodchip need air to keep smoking.
- Whether to open or close the exhaust vent is decided to be 30% open based on the experimental trials with sensory tests, considering operational efficiency, smoking flavor remaining on the product, etc.

【Conditioning】

- Smoked products should be aging to get *umami*, hidden taste, by conditioning at least overnight.
- Conditioning helps to decrease Aw.

2) Step 6 (Use of high gas barrier pouch)

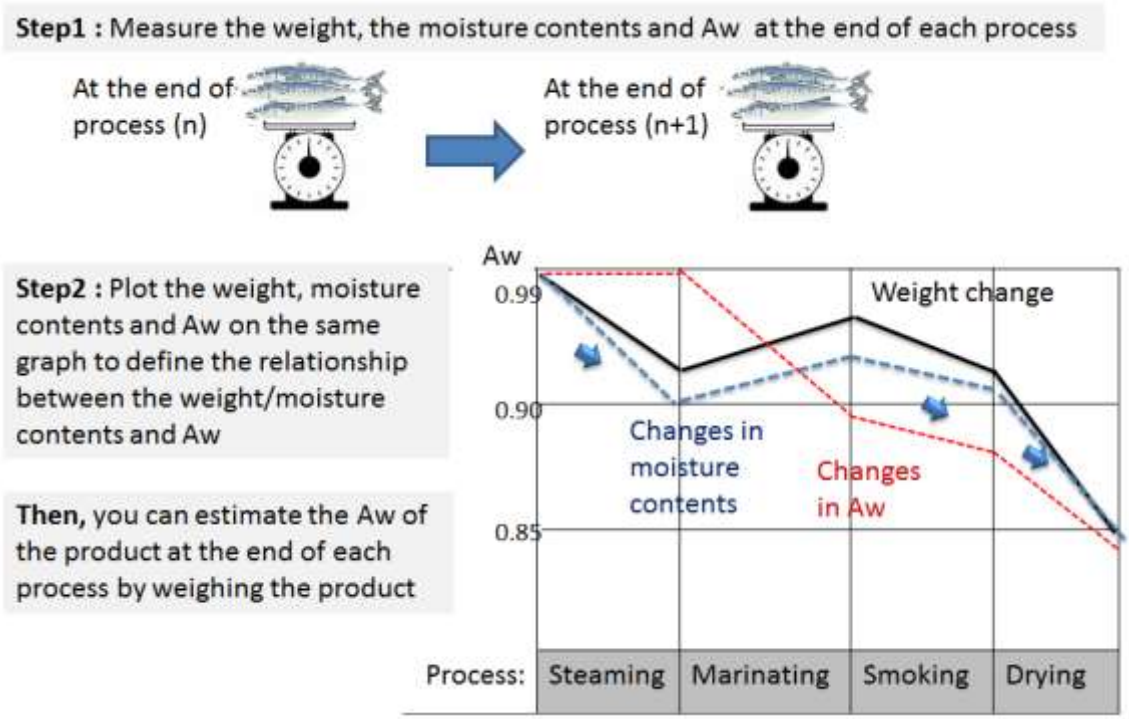
- The smoked fish product of the proposed processing flow, following the preset standard operation procedure, was verified its effectiveness in terms of long shelf life through sensory test after 1 year.
- Comparing the samples in KON and ON, it was revealed that smoking flavor of the samples in ON became very slight, since ON doesn't have flavor barrier.
- The samples in ON were slightly inferior to those in KON in terms of taste and color. On the other hand, oxidation odor didn't seemed significantly for the samples in ON, since soy sauce has function to prevent oxidation.
- If compared with OPP, the change would be more visible.

3) Step 7 (Boil pasteurization)

- The longer time it takes and the higher the temperature of hot water is, the harder the product becomes. Sensory test can be conducted easily.

(5) Recommendation for Practical Control

In actual operation of companies, measuring of Aw, water contents, and weight in each process is not realistic due to measurement time. Therefore it is recommendable that Aw and water contents will be estimated by weight of samples at each end of processes, once the relation of three values is revealed.



Source: Prepared by the JICA Project Team

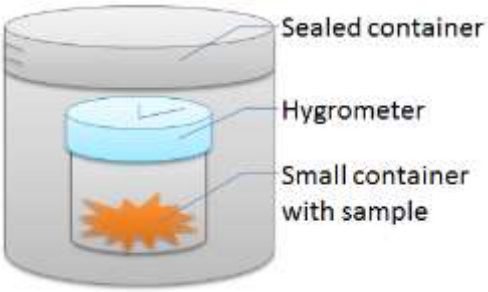
Figure 1-3-3 How to Prepare Index of Aw Using Measurable Values

In case the Aw meter is not available, the simple way explained below can be applied using two containers and hygrometer.

i. Put sample in a small container (glass or plastic).
ii. Put small hygrometer (digital or analog) on the small container.
iii. Put all in a big container and close the lid.
iv. Keep several hours depending on the sample size. About 3 hours in case of half of fillet.

Once the value of hygrometer has stabilized, read the value and it is the so-called equilibrated relative humidity. Aw of the sample will be obtained from the equilibrated relative humidity (divided by 100). For example, 85% of humidity in the container means 0.85 of Aw of the sample.

Aw meter



Simple method

(6) Assessment of viability of the proposed technology and methods

With development of a smoked fish product and its packaging good for storing and distribution for a longer time at the ambient temperature and palatable in the category of "smoked" fish product, following effects are expected:

1 Reduction of unsold loss caused by short shelf-life,
2 Value adding and market development in terms of location and new type of consumers attracted by the new feature of the product, resulting in increase in sales, and
3 Saving of costs to have required for frozen storage and distribution

The estimated effects expected from the new product and packaging is P. 61/kg (or P. 30,610/500kg (average production volume per day for medium-sized enterprises of smoked fish)). For detail, see Table 1-3-5.

Table 1-3-5: Expected Economic Effects of Application of the Proposed Technology/Method

Smoked Fish (1)

Development of a new smoked fish product good for storing and distribution at the ambient temperature

1) Vacuumed packaging after improving preservative quality by cooking at low-temperature using pre-mixed seasoning liquid and hot smoking,

2) Boil sterilization for prevention of mold growth

3) Prevention of oxidation and browning during storage using high-barrier film for packaging

➡ **Effect:** 1) Reduction of unsold loss caused by short shelf-life, 2) value adding and market development in terms of location and new type of consumers attracted by the new feature of the product, resulting in increase in sales, and 3) saving of costs to have required for frozen storage and distribution

Practice/ actions	Revenue and costs/expenditure						Basis of the revenue/costs/expenditures estimate
			Per kg of product			Amount/500kg (production/day of medium-sized enterprise)	
			Volume	Unit price	Amount		
Current practice	Sales (for local market)	Shipment	1	260	260	130,000	Unsold loss is not assumed with assumption of production by order
		Loss	0.0	260	0	0	
		Net sales			260	130,000	
	Costs & expenses	Production cost	1	104	104	52,000	Assuming 40% of the sales value
		Low-temperature storage	1	11.3	11.3	5,650	1 day storage before shipping (P. 11.3/kg-day (cost of electricity))
		Sub-total (*2)			115	57,650	
	Balance (*1)				145	72,350	
Proposed practice New type of smoked fish of long shelf-life at the ambient temperature	Sales (for local market)	Shipment	1.2	286	343	171,600	Assumption of 10% increase in the sales price, and 20% increase in the sales volume. No unsold loss.
		Loss	0.0	286	0	0	
		Net sales			343	171,600	
	Costs & expenses	Production cost	1.2	114.4	137.28	68,640	Assuming 10% increase in unit production cost
		Low-temperature storage	1.2	0	0	0	
		Sub-total (*2)			137	68,640	
	Balance (*1)				206	102,960	

▼Increase in profit/increase in required investment (Δ*1/Δ*2): (102,960-72,350)/(68,640-57,650)=2.8

(7) Further Challenges

Table 1-3-6 shows the suggestion for possible improvement of marketability with differentiation of your product from that of competitors.

Table 1-3-6 Possible Improvement

Improvement factors	Suggestion on possible way of improvement
Smell	Use of selected wood chips good for better smell.
Flavor	Use of herbs and/or spices: the product can have different flavor from the current one.
Color	Use of light color soy sauce: Not too dark color or light color will make the product more attractive.
Softness	Avoid too much heating and too much drying.
Saltiness	Adjust the balance of salt and sugar contents in the seasoning mixture: You can reduce the saltiness for good taste and for good health.
Graphic design of package	Improve the graphic design of package and label: Appealing the feature of your products with branding. Support from PTD is available.

Source: Prepared by the JICA Project Team

1.3.2 Reduction of Mechanical Damage during Transportation

(1) Issues focused:

Mechanical damage on the smoked fish during transportation is significant because of over-stuffing the products in the transport packages mainly corrugated boxes.

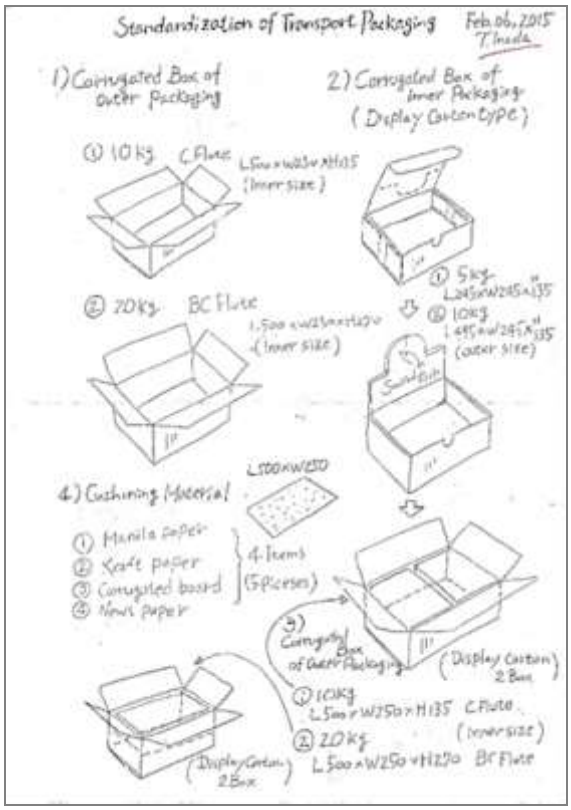
(2) Proposed packaging

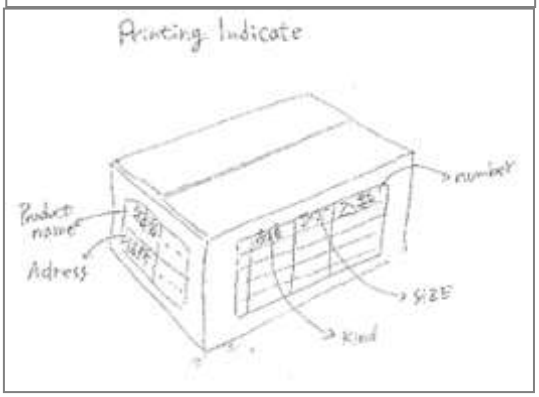
Promotion of use of transport package of standard volume to prevent over-stuffing such as 10kgs and 20kgs, etc. is recommended.

The following drawing and image picture shows a sample packaging designed as the standard sized transportation container which can be used also as a package for display at retail shops (the detail dimension of the box should be determined according to the size of the individual package).

(3) Output of the packaging

The following drawing and image picture are just for reference.





(4) Assessment of viability of the proposed packaging

With development of a standardized size transport packaging (box) to avoid damages during transportation and handling caused by overstuffing, the loss caused by discounting the sales price because of damage of the product during transportation can be reduced by P. 2/kg (or P. 1,000/500kg ((average production volume per day for medium-sized enterprises of smoked fish). For detail, see Table 1-3-7.

Table 1-3-7: Expected Economic Effects of Application of the Proposed Technology/Method

Smoked Fish (2)

Development of a standardized size of transport packaging (box) to avoid damages during transportation and handling caused by overstuffing

➡ **Effect:** Reduction of loss caused by discount of sales price to be offered because of damage of the product during transportation (or loss of total value)

Practice/ actions	Revenue and costs/expenditure						Basis of the revenue/costs/expenditures estimate
			Per kg of product			Amount/500kg (production/day of medium-sized enterprise)	
			Volume	Unit price	Amount		
Current practice	Sales (for local market)	Shipment	1	260	260	130,000	- No unsold loss is assumed with assumption of production by order - Damage rate due to over-stuffing: 8% (2 bags of the total 25 bags) to be sold at 20% discounted price of the sales price
		Loss	0.08	52	4	2,080	
		Net sales			256	127,920	
	Costs & expenses	Re-use corrugated box	0.083	20	2	830	Re-use corrugated box for 12kg: P. 20/kg
		Sub-total (*2)			2	830	
	Balance (*1)				254	127,090	
Proposed practice New type of smoked fish of long shelf-life at the ambient temperature	Sales (for local market)	Shipment	1	260	260	130,000	
		Loss	0	0	0	0	
		Net sales			260	130,000	
	Costs & expenses	Standard corrugated box	0.1	40	4	2,000	Corrugated box for 10kg: P. 40/kg
		Sub-total (*2)			4	2,000	
	Balance (*1)				256	128,000	

▼Increase in profit/increase in required investment (Δ*1/Δ*2): (128,000-127,090)/(2,000-830)=0.708

1.3.3 Development of Packaging Graphic Design

(1) Requirements of the packaging to be developed

The packaging graphic design to be developed should promote the positive brand image of Philippino smoked fish in both the international market and the domestic market. For this purpose, the package design needs to:

1. Reflect the brand concept that represents the unique value of the new style smoked fish and thus distinguishes it from other smoked fish in general;
2. Establish the brand identity by ensuring the uniform tone and style of visual appearance across different types of packaging; and
3. Provide sufficient information about the product, such as smoky flavor and ready-to-eat, serving suggestions, and local cultural implications, to encourage adoption by the target consumers who are not familiar with the new type of smoked fish.

(2) Proposed packaging graphic design for smoked fish

1) Individual packaging of smoked fish

Using a header type of label as commonly used in the Philippines is suggested. This type is supposed for packed by vacuum packaging.

A brand name named "Tech's Kitchen", which means "Technology's Kitchen" is proposed. The product photo on a dish easily captures the consumers' attention and makes us feel sizzling of the product.

2) Individual packaging box for smoked fish

Similar to the individual labeling of the smoked fish, the packaging box gives more information such as nutrition information to add more value to the product. On the back side, some examples of recipes using the smoked fish with rice, pasta, salad and so on are introduced. QR codes are also added to the box.

This package was developed to be adopted in several manners of storage such as freezing, cold storage, and at ambient temperature.

3) Display box- type A and Type B

2 types of display box for the smoked fish are proposed to easily transform a transport box to a marketing material and also to be adapted to various situation of shop display. Flexo technique is used to translate a photo to be directly printable graphic to a brown box.

There are 2 patterns of 10 kg and 5kg. They are supposed to be used as collection boxes for transport packaging to put 2 cases and 4 cases of individual packaging each.

4) Transport packaging of smoked fish

Similar graphic is used as well for the transport packaging to give a family look feel of the product as well as to add more value to the product. More information of the product is indicated.

As common feature for both individual package and collecting box, logo type and symbol mark are uniformed to make a series of brand image. Brown box also assists the image. Sales copy, which is still dummy, is also added to promote the place, where the fish was harvested.

[For reference]

The packaging graphic designs before updating above mentioned are shown as below.

(3) Verification of effectiveness

These proposed packaging graphic designs were highly appreciated by the participants of the smoked fish training held on 9-10 Mar.

Part 2: Fruits and Vegetables (Ver. 5.0)

2.1 Overview

2.1.1 Basics of Freshness Preservation of Fruits and Vegetables

Fruits and vegetables start losing their freshness right after harvest. Physiological activities of the produce itself, namely respiration, transpiration, and ethylene production, are the causes for freshness deterioration. To put it other way around, freshness deterioration of fruits and vegetables can be delayed or suspended by controlling those physiological factors. Table 2-1-1 outlines basic ways to preserve freshness.

Table 2-1-1 Means to Prevent Freshness Deterioration of Fruits and Vegetables

	Respiration	Transpiration	Ethylene production
Cause of deterioration	1) Decrease in nutrients 2) Conversion of sugar to starch	1) Loss of moisture	1) Accelerated respiration
Sign of deterioration	- Loss of sugars, acids and vitamins - Color deterioration - Yellowing	- Wilting - Loss of weight - Loss of luster	- Fading of green color - Progression of yellow color
Means to prevent deterioration	a) Restrain respiration by lowering the temperature - Pre-cooling - Cold storage b) Restrain respiration by adjusting the composition of environmental gas - Controlled storage - MAP	a) Prevent transpiration by cooling the vegetable - Pre-cooling - Cold storage b) Prevent transpiration by packaging the vegetable - Film-wrapping	a) Restrain ethylene production by lowering the temperature b) Restrain ethylene production by adjusting the composition of environmental gas c) Remove the produced ethylene - Use of ethylene absorber is not common for vegetables

Source: Prepared by the JICA Project Team

Patterns of respiration, transpiration and ethylene production/sensitivity differ by kind of fruit or vegetable. Accordingly, an effective combination of freshness-preserving measures should be selected by considering the characteristics of the target fruit or vegetable.

(1) Respiration rate

Leaf vegetables and immature beans have a high respiration rate while fruit vegetables and root vegetables shows lower respiration rates. Importance of cooling the vegetable increases as the respiration rate is higher.

Table 2-1-2 Levels of Respiration Rate by Type of Vegetable

Kind of vegetable	Respiration rate		
	High	Moderate	Low
Leaf vegetables and immature beans	✓		
Fruit vegetables		✓	
Root vegetables			✓

Source: Prepared by the JICA Project Team

(2) Characteristics of transpiration

Transpiration of some fruits and vegetable is suppressed under low temperatures, while that of other fruits and vegetables is not significantly influenced by the temperature. For the fruits and vegetables on which low temperature is not effective in reducing the transpiration rate, wrapping the produce with plastic film is recommended as effective means to slow transpiration.

Table 2-1-3 Means to Suppress Transpiration

Kind of vegetables: (For the vegetable, is low temperature effective in preventing transpiration?)	Effective means of controlling transpiration	
	Pre-cooling & cold storage	Film-wrapping
A Very effective	✓	
B Fairly effective	✓	
C Not effective	✓	✓

Note: ✓ means applicable.
Source: Prepared by the JICA Project Team

(3) Low temperature

Low-temperature injuries are rarely observed on fruits and vegetables. Freshness deterioration due to insufficient cooling is more serious problem than low-temperature injuries. **Low temperature is the most effective way** of decreasing the respiration and transpiration rates.

Table 2-1-4 Ways to Create Low-Temperature Conditions

Pre-cooling	Differential pressure cooling, hydro-cooling, or vacuum cooling
0℃	Crushed ice in a water-proof paper box or EPS box
10℃	Refrigerated container
15 – 30℃	MAP under stable temperature

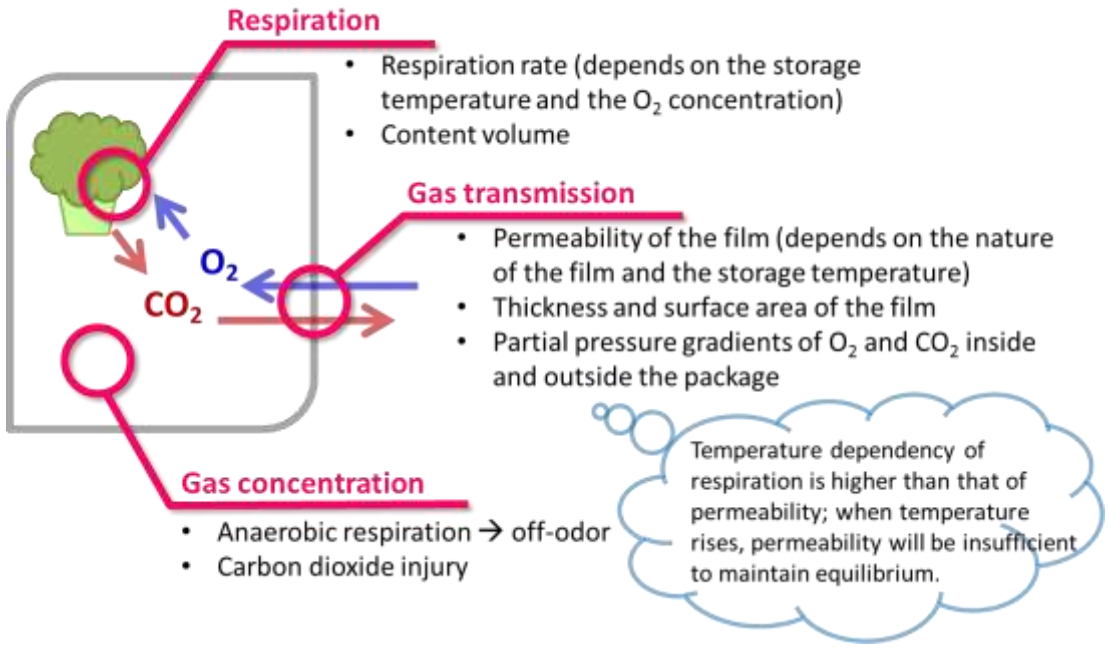
Source: Prepared by the JICA Project Team

MAP is an effective method in lowering the respiration rate under higher stable temperature. When the distribution temperature is very low, however, effectiveness of MAP is not so significant.

2.1.2 Design of Modified Atmosphere Packaging (MAP)

(1) What is modified atmosphere packaging (MAP)?

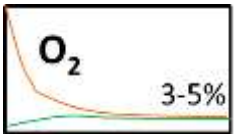
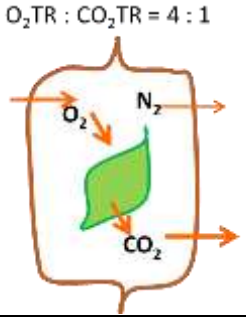
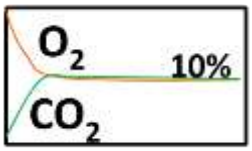
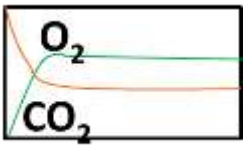
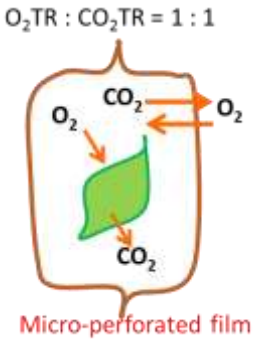
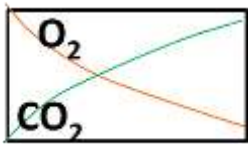
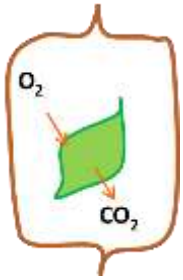
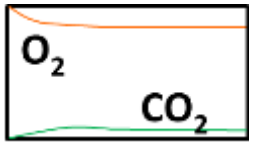
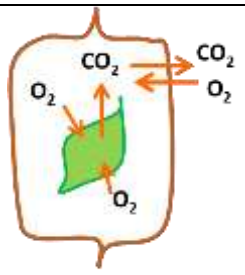
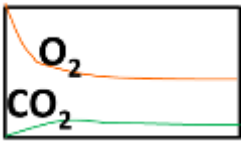
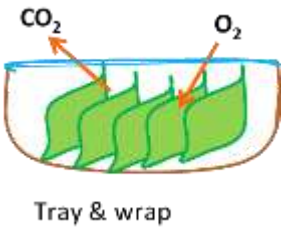
MAP can be defined as the enclosure of food in a package in which **the atmosphere inside the package is modified or altered to provide an optimum atmosphere for increasing shelf life** and maintaining quality of the food.



Source: Prepared by the JICA Project Team

Figure 2-1-1 Factors of MAP Design

Table 2-1-5 Types of MAP

Type of packaging	Characteristics
Equilibrium (E) type MAP  	• LDPE, OPP, HDPE, etc. • Low temperature • Volume change (20%)
Perforated (P) type MAP   	• Any kind of film, pouch or tray & top-seal • NO temp. fluctuation • High accumulation of CO_2 • No volume change
Dole (D) type MAP  	• PET, ON, OPP pouch (OPP is better) • The lower the temperature, the longer the shelf life • Temp. fluctuation shortens the shelf life • High CO_2 concentration
Open-air package  	• OPP with holes (anti-fogging, etc.) • The lower the temperature, the better the freshness preservation effects • Tolerant of temperature fluctuation
Semi-MA  	• OPS tray with PVC wrap • The lower the temperature, the better the freshness preservation effects • Tolerant of temperature fluctuation

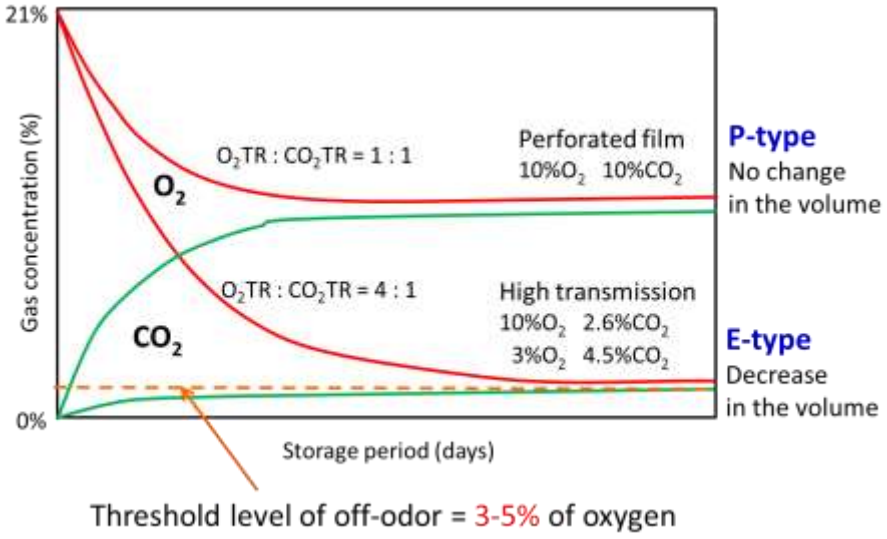
Source: Prepared by the JICA Project Team

Different types of MAP are available for selection according to characteristics of the produce, expected environmental conditions during distribution, and costs and technologies required for packaging. Tables 2-1-5 and 2-1-6 as well as Figure 2-1-2 explain advantages and disadvantages of each type of MAP.

Table 2-1-6 Comparison between Types of MAP for Fresh Produce

Type of MAP	Temperature fluctuation	CO_2 accumulation	Volume change	Form of packaging
Equilibrium (E) type MAP	Small effect on gas concentration	Low	Decrease (> 20%)	Pouch (Limited kinds of film)
E-type MAP + gas flush (active MAP)	Small effect on O_2 concentration	Low	Decrease	Pouch (Limited commodity)
Perforated (P) type MAP	Big effect on CO_2 concentration	High	No change	Tray & top-seal (Any kind of film)
P-type MAP + gas flush (active MAP)	Less effect to CO_2 concentration	Less than P-type MAP	No change	Tray & top-seal
Dole (D) type MAP	Big effect on the shelf life	High	Small change	Pouch

Source: Prepared by the JICA Project Team



Source: Prepared by the JICA Project Team

Figure 2-1-2 P-type and E-type of MAP for Fresh Fruits and Vegetables

(2) How to design MAP for a particular commodity?

Designing MAP involves 1) deciding a proper gas composition to keep freshness of the target commodity, 2) measuring the commodity's respiration rate at the gas composition, and 3) selecting a film that has the oxygen transmission rate same as the respiration rate.

Box 2-1-1 Background theory for MAP design

The flux of oxygen through the packaging film is given by the formula below.

$$F_{O_2} = K_{O_2} \cdot A \cdot \left(0.21 - P_{O_2}\right)$$

F_{O_2} : O_2 flux through the film per unit time
K_{O_2} : O_2 permeability through the film (ml/24hr. , m^2, atm)
A : Film surface area (m^2)
P_{O_2} : Partial pressure of O_2 inside the package

The consumption of oxygen through respiration of the vegetable or fruit in a package is given by the formula below.

$$R_{O_2} = B_{O_2} \cdot W$$

R_{O_2} : O_2 consumed through respiration per unit time
B_{O_2} : O_2 consumption rate per unit weight (ml/24hr. , kg)
W : Sample weight (kg)

At equilibrium, the O_2 flux (F_{O_2}) and O_2 consumption (R_{O_2}) should be equal.

$$K_{O_2} \cdot A \cdot \left(0.21 - P_{O_2}\right) = B_{O_2} \cdot W$$

Rearranging the equation above,

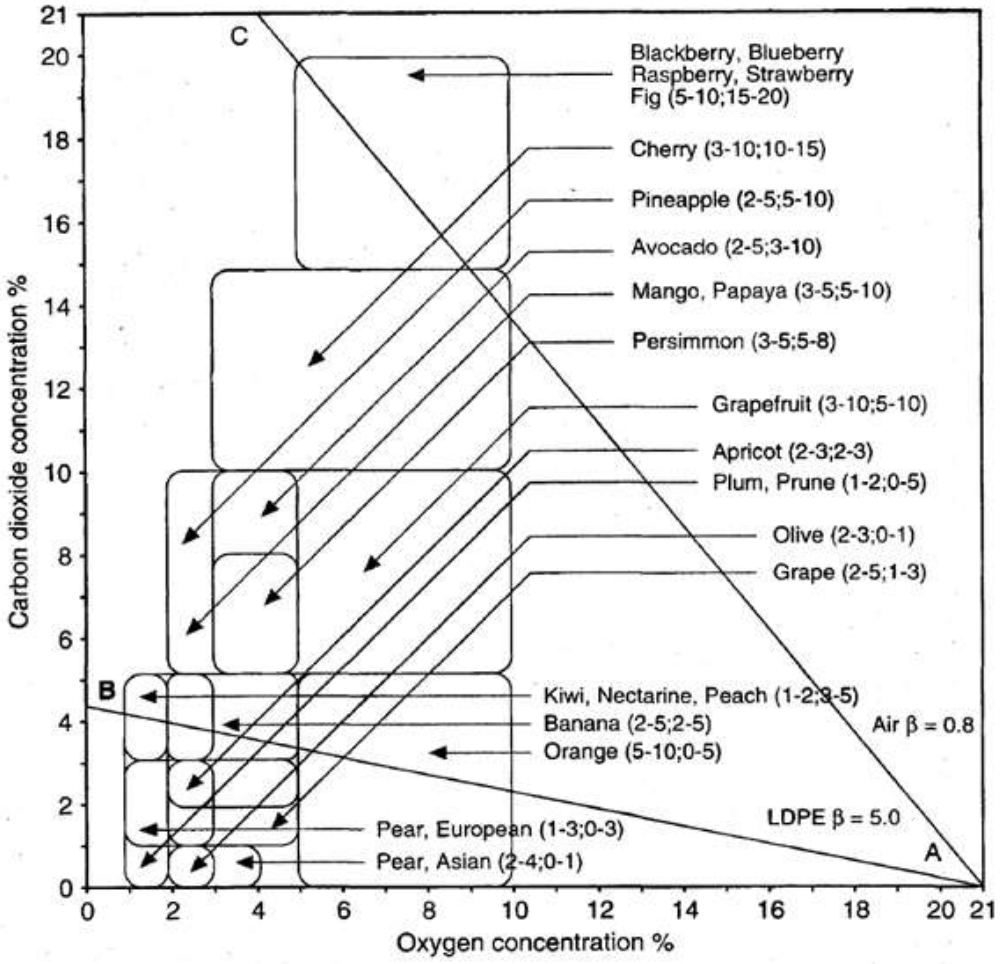
$$K_{O_2} \cdot A = \frac{B_{O_2} \cdot W}{0.21 - P_{O_2}}$$

Therefore, the required oxygen permeability will be estimated based on the respiration rate under given conditions.

The key conditions affecting the respiration rate are the oxygen concentration and the storage temperature. Each kind of vegetable and fruit has a particular range of gas composition suitable for preserving its freshness.

1) Deciding a proper gas composition to keep freshness of the target commodity

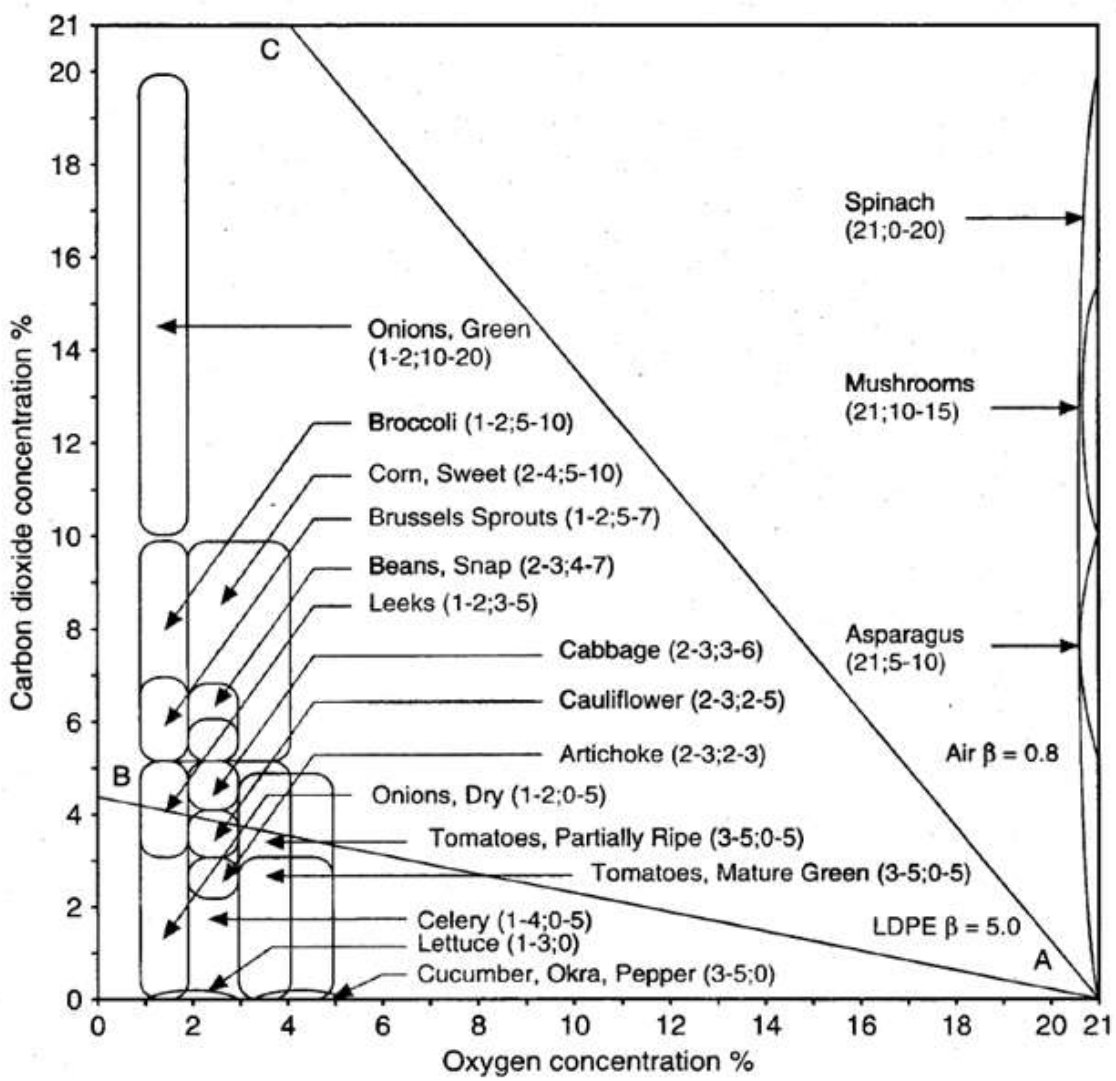
Each kind of fruit or vegetable has the optimum composition of the oxygen and the carbon dioxide concentrations for preserving its freshness without being damaged by negative effects of the modified gas condition. Therefore the first step of designing MAP is to know the suitable range of gas composition for the target commodity by referring to existing literatures. Figures 2-1-3 and 2-1-4 present recommended gas composition for fruits and vegetables respectively, followed by tolerable limits of gas concentration in Tables 2-1-7 and 2-1-8.



Note: $\beta = \frac{K_{CO_2}}{K_{O_2}}$ where K_{CO_2} stands for CO_2 permeability and K_{O_2} stands for O_2 permeability.

Source: Kader, A. A., Singh, R. P., and Mannapperuma, J. D., Technologies to extend the refrigerated shelf life of fresh fruits, In Food Storage Stability, Taub, I. A. and Singh, R. P., Eds., CRC Press, Boca Raton, FL, 1998, chap. 16.

Figure 2-1-3 Recommended Modified Atmospheres for Storage of Fruits



Note: $\beta = \frac{K_{CO_2}}{K_{O_2}}$ where K_{CO_2} designates CO_2 permeability and K_{O_2} designates O_2 permeability.

Source: Kader, A. A., Singh, R. P., and Mannapperuma, J. D., Technologies to extend the refrigerated shelf life of fresh fruits, In *Food Storage Stability*, Taub, I. A. and Singh, R. P., Eds., CRC Press, Boca Raton, FL, 1998, chap. 16.

Figure 2-1-4 Recommended Modified Atmospheres for Storage of Vegetables

Table 2-1-7 Classification of Fruits and Vegetables according to their Tolerance to Reduced O_2 Concentrations

Minimum O_2 concentration tolerated (%)	Commodities
0.5	Tree nuts, dried fruits and vegetables
1.0	Some cultivars of apples and pears, broccoli, mushrooms, garlic, onions, most cut or sliced (minimally processed) fruits and vegetables
2.0	Most cultivars of apples and pears, kiwifruit, apricots, cherries, nectarines, peaches, plums, strawberries, papaya, pineapple, olives, cantaloupe, sweet corn, green beans, celery, lettuce, cabbage, cauliflower, Brussel sprouts
3.0	Avocados, persimmon, tomatoes, peppers, cucumber, artichoke
5.0	Citrus fruits, green peas, asparagus, potatoes, sweet potatoes

Source: Kader, A. A., Zagory, D., and Kerbel, E. L., *CRC Crit. Rev. Food Sci. Nutr*., 28, 1989.

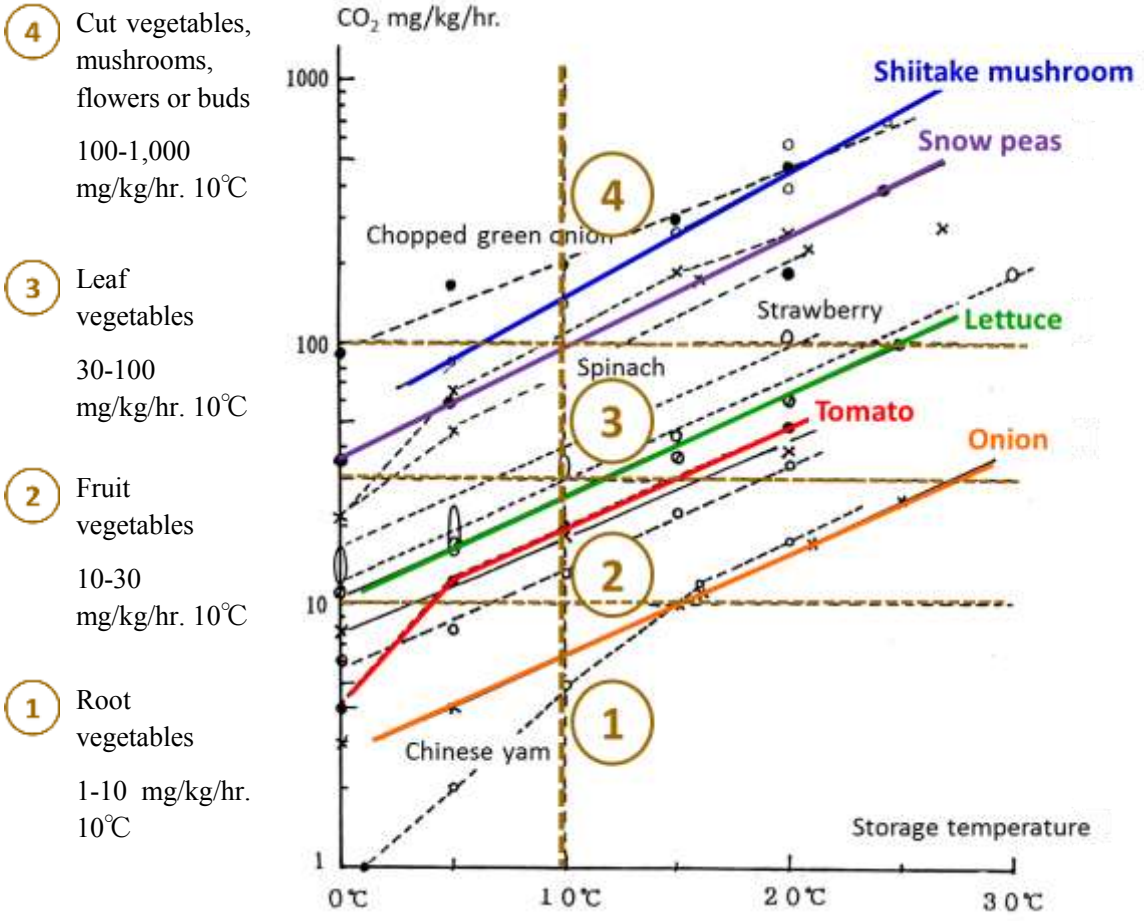
Table 2-1-8 Classification of Fruits and Vegetables according to their Tolerance to Elevated CO_2 Concentrations

Maximum CO_2 concentration tolerated (%)	Commodities
2	Golden Delicious apples, Asian pears, European pears, apricots, grapes, olives, tomatoes, peppers (sweet), lettuce, endive, Chinese cabbage, celery, artichoke, sweet potatoes
5	Apples (most cultivars), peaches, nectarines, plums, oranges, avocados, bananas, mango, papaya, kiwifruit, cranberries, peas, peppers (chili), eggplant, cauliflower, cabbage, Brussels sprouts, radishes, carrots
10	Grapefruit, lemons, lime, persimmon, pineapple, cucumber, summer squash, snap beans, okra, asparagus, broccoli, parsley, leeks, green onions, dry onions, garlic, potatoes
15	Strawberries, raspberries, blackberries, blueberries, cherries, figs, cantaloupe, sweet corn, mushrooms, spinach, kale, Swiss chard

Source: Kader, A. A., Zagory, D., and Kerbel, E. L., *CRC Crit. Rev. Food Sci. Nutr.*, 28, 1989.

2) Measuring the commodity's respiration rate at the selected gas composition

Figure 2-1-5 shows how the respiration rate of vegetables changes according to the storage temperature. As the respiration rate of fresh fruits and vegetables changes in response to the temperature and the oxygen concentration, the MAP to be developed must be adjusted to the expected respiration rate at the planned conditions of gas composition and storage temperature. Therefore the second step of designing MAP is to measure the respiration rate of the target commodity under the planned conditions.



Source: Takasuke Ishitani, et.al., "Burokkori-to no Sendo-hoji Ko-hoso [Individual Packaging for Freshness Preservation Applied to Broccoli]," Second Annual Meeting of Society of Packaging Science and Technology Japan, 1993. Partly modified.

Figure 2-1-5 Respiration Rate of Vegetables

Table 2-1-9 provides rough figures of the respiration rate of vegetables as a reference for planning trial experiments.

Table 2-1-9 Classification of Vegetables according to Respiration Intensity

Class	Respiration Intensity at 10℃ (mg CO_2 kg^{-1} h^{-1})	Commodities
Very low	Below 10	Onions
Low	10-20	Cabbage, cucumber, melons, tomatoes, turnips
Moderate	20-40	Carrots, celery, gherkins, leeks, peppers, rhubarb
High	40-70	Asparagus (branched), eggplant, fennel, lettuce, radishes
Very high	70-100	Beans, Brussel sprouts, mushrooms, savory cabbage, spinach
Extremely high	Above 100	Broccoli, peas, sweet corn

Source: Weichmann, J., Low oxygen effects, In *Postharvest Physiology of Vegetables*, Weichmann, J., Ed., Marcel Dekker, New York, 1987. chap. 10.

3) Selecting a film that has the gas transmission rate same as the respiration rate

Finally, a film pouch will be designed to balance the oxygen influx through the film and the oxygen consumed through respiration of the commodity inside. The oxygen influx depends on the oxygen permeability of the film and the surface area of the pouch. The oxygen consumed through respiration depends on the respiration rate and the volume of commodity packaged.

The oxygen permeability of a film changes under different temperatures as shown in Figure 2-1-6. Note that the rate of change to the temperature is different for the oxygen permeability of the film and for the respiration rate of the fresh fruit or vegetable. That is why the MAP can be applied only when the storage/distribution temperature is kept stable. Figures of the oxygen permeability of major films are provided in Tables 2-1-10 and 2-1-11.

On the other hand, micro-perforated films are increasingly adopted for their stability of oxygen permeability which is quasi-independent from temperature changes. Box 2-1-2 explains the process of measuring the permeability of micro-perforated films.

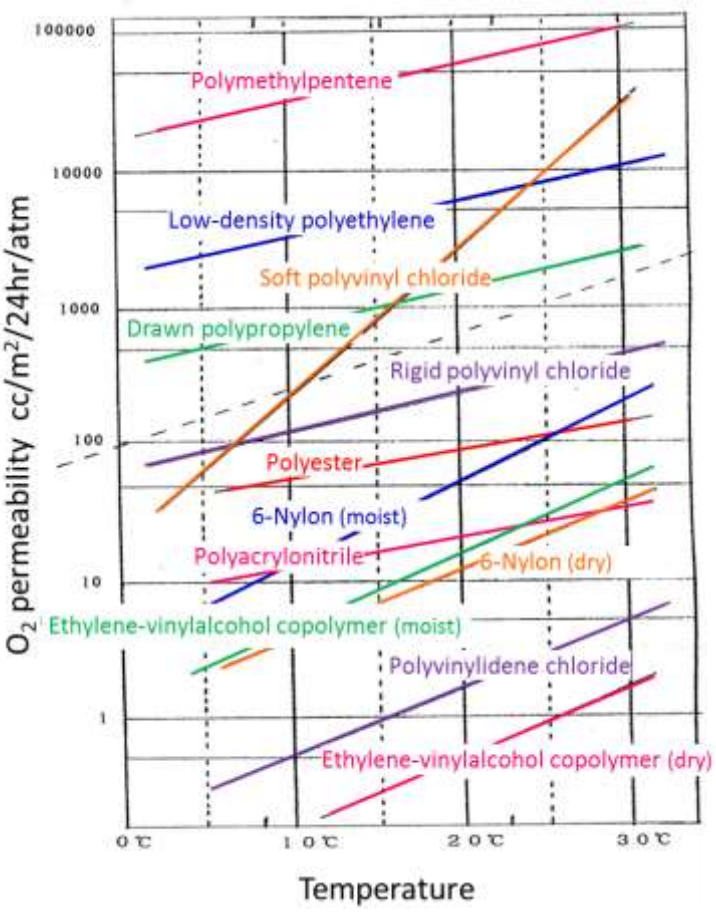


Figure 2-1-6 Oxygen Permeability of Plastic Films (20μm)

Table 2-1-10 Oxygen and Carbon Dioxide Permeability of Plastic Films

Film	O_2 permeability (ml/m^2, 24hr., atm / 25μm)	CO_2 permeability (ml/m^2, 24hr., atm / 25μm)	Ratio (K_{CO2}/K_{O2})
EVA (10%)	9,960	52,300	5.3
LDPE	7,900	42,500	5.3
HDPE	2,900	9,100	3.1
CPP	3,800	12,600	3.3
OPP	2,500	8,500	3.4
O-Nylon	30	-	-
PET	110	320	2.9
PB	50,000	360,000	7.3
PMP	85,000	240,000	2.9

Table 2-1-11 Plastic Films for MAP

Film	Thickness (μm)	Oxygen transmission cc/m2-day-atm (24°C)	Water vapor transmission g/m2-day (40°C)
Polymethylpenten	25	47,000	110
Polybutadiene	30	13,000	200
Ethylene vinyl acetate copolymer	30 wrap	10,000 - 13,000	80 - 520
Soft polyvinyl chloride	30 wrap	10,000	80 - 1,100
(very thin) HDPE	12 wrap	10,000	17
Polystyrene	30	5,500	133
Poly lactic acid	<OPS	< Same level as OPS >	
Low-density polyethylene (LDPE)	30	6,000	18
High-density polyethylene (HDPE)	30	4,000	7
Casted polypropylene	30	4,000	8
Oriented polypropylene (OPP)	20	2,200	5
Oriented nylon	15	75	134
Polyester	12	120	25

E-type
Semi-open type
P-type
D-type

Source: Takasuke Ishitani, 1993, in Hiroshi Osuga (ed.), "Shin Syokuhin Hoso-yo Firumu [New Edition: Food Packaging Films]," 1999. Partially modified.

Box 2-1-2 Permeability of Micro-perforated Films

The oxygen transmission volume through pinhole(s) is obtained by the formula below. **Temperature change has marginal effect on gas transmission through pinholes**.

$$F_{pin} = \frac{D_{rel}(c - c_0)A_{pin}t}{l}$$

F_{pin} : Gas flux through pinhole per unit area and unit time
D_{rel} : Mutual diffusion coefficient (N_2/O_2)
(= 0.206 ($10^{-4}m^2$, sec^{-1}) at 20 ℃)
$c - c_0$: Difference of O_2 concentration
A_{pin} : Area of the pinhole(s) (πr^2)
t : Time (hour)
l : Length of the pinhole (thickness of the film)

The diffusion coefficient depends on the temperature and will be estimated by using the formula below.

$$D_T = D_0 \left(\frac{T + 273}{273}\right)^{1.75\sim2}$$

D_T : Diffusion coefficient at T ℃
D_0 : Diffusion coefficient at 0 ℃

2.2 Broccoli and Cauliflower

2.2.1 Current Practice and Needs for Improved Post-harvest Handling and Packaging Technologies

(1) Feature of broccoli and cauliflower

Both broccoli and cauliflower are featured as high-value vegetables targeting upscale markets. However, very high physiological activity of these vegetables causes rapid quality deterioration after harvesting as compared to other fresh vegetables.

(2) Current post-harvest and distribution practice

The following are the post-harvest and distribution practice of broccoli and cauliflower currently seen in Benguet:

Table 2-2-1 Current Post-harvest and Distribution Practices of Broccoli and Cauliflower

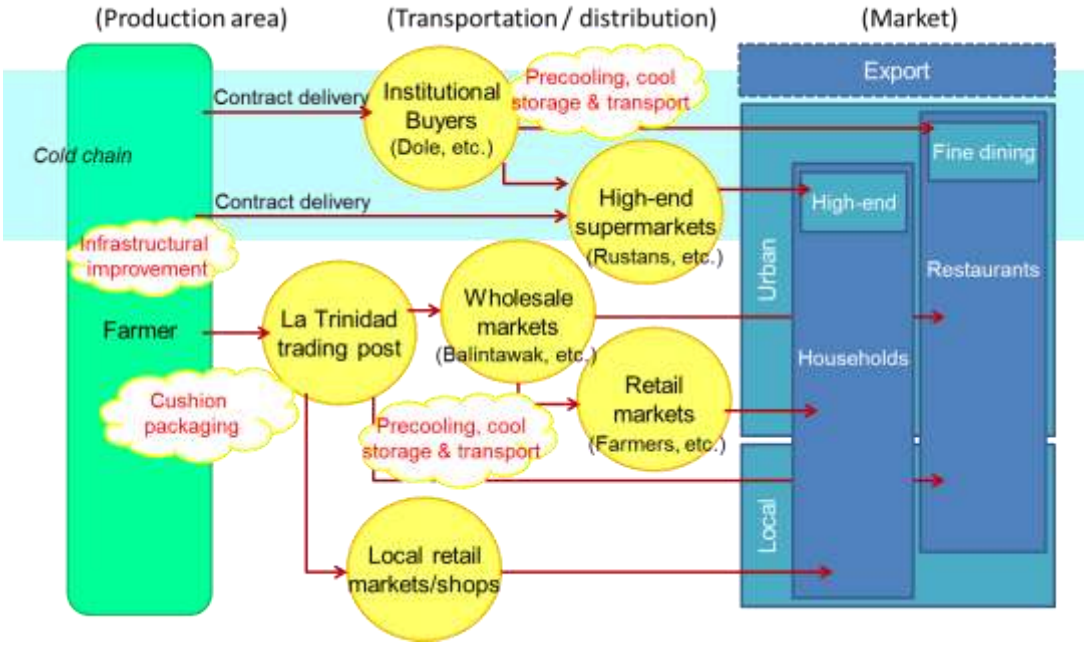
Current post-harvest and distribution practice		Remarks
Post-harvest treatment after harvesting	Hang upside down (or lay on ground) harvested broccoli/cauliflower in shade	To let foliage wilted to cover the floret cluster for protection
Packing for transportation to local trading post by Jeepney	Use of: - Woven plastic sack (50 kg) - Bamboo basket, or - Used corrugated box/sheet etc.	Mostly the broccoli and cauliflower are placed randomly in the container/ package. Some advanced farmers use plastic container placing the vegetables horizontally.
At the trading post at La Trinidad	Case 1: Trim and reduce foliage	Wrap the floret cluster by the remaining foliage for protection
	Case 2: Trim into "mushroom" shape removing the foliage	Trimming for the final shape of the product for the transport efficiency
Packing for transportation to urban consumption areas	Newspaper covering floret clusters or randomly placed in:	Protect the floret cluster and absorb excess moisture inside the bag
	1) Polyethylene bag, or	Plastic crate is not used because of lack of returning system of the crate, except for the case of direct delivery to specific institutional users
	2) Reused corrugated box	
At retail shops	Remove foliage and trim them into "mushroom" shape	Remove damaged parts before displaying in store
	Wrap with PVC film	To keep good appearance for a longer time period

Source: Prepared based on the results from field survey conducted in April 2013 in Benguet

Hung in shade after harvesting for use of wilted foliage as protection

Transport packaging and trucking (La Trinidad trading post)

(3) Distribution of broccoli and cauliflower and emerging needs



Source: Prepared based on interviews conducted in April 2013 with broccoli/cauliflower growers and traders in Benguet as well as traders at Balintawak Wholesale Market in Manila

Figure 2-2-1 Distribution of Broccoli and Cauliflower and Emerging Needs

Broccolis are classified according to the size: large, medium, and small. The medium class is the acceptable grade and distributed to hotels, restaurants and supermarkets and other institutional buyers. The large and small classes, on the other hand, are regarded as the second grade which is to be dealt in local and urban wet markets.

(4) Current issues on post-harvest and distribution process of broccoli and cauliflower in the Philippines

Issues recognized in the farm production and primary distribution level and those recognized in the downstream distribution levels differ significantly. The former, i.e. production site (Benguet), considers damages to the produce are a problem but pays little attention to the need for freshness preservation in the major markets. The following discusses the issues recognized in the different distribution levels.

1) Issues raised at farm production and primary distribution level

The stakeholders at the farm production and primary distribution level recognize the following issues.

a) Difficulty to adjust shipment timing

Naturally, harvested broccolis/cauliflowers have a short period of freshness preservation; two to three days at an ambient temperature. Production areas do not have a method of short/long-term storage of harvested broccolis/cauliflowers currently, and farmers have to ship the produce immediately after harvesting at a proper maturation stage, even when the price is low.

b) Physical and physiological damages during transportation from production sites

Harvested broccolis/cauliflowers are either shipped by the farmer to the trading post in Benguet or bought at the farm gate by a buyer who transports the produce to the trading post, local markets, or Manila markets. Considerable part of the produce is damaged during this transportation process; as high as 40-60% of the produce is damaged in the case of a farmer bringing his produce into the trading post.

Yellowing is observed on broccolis arriving in the trading post or the cold storage in Benguet after four to five hours of transportation from remote mountain areas such as Kabayan and Mountain Province.

Causes of such damages include the following.

- Mechanical shocks during transportation
- Compression due to over-stuffing

c) Poor cost-efficiency of transportation owing to use of foliage as protection

Some farmers practice trimming of the floret cluster in the way which is called as “umbrella cut” or “mushroom cut.” The majority, however, does not remove the foliage but wrap it around the floret cluster as means of protection. Harvested broccolis/cauliflowers are dried in the shade for about half a day and then the floret cluster is wrapped with wilted leaves on the stem, followed by packing in a bamboo basket, plastic crate, or PE bag for shipment. The produce is trimmed by removing excess leaves at the trading post, which leaves the sellable product as small as 33% of the volume transferred from the farm. That is, two thirds of the transported volume is wasted and the cost-efficiency of transportation is quite low.

d) Missed-out value which could be realized through post-harvest treatment including trimming and packaging

The price of trimmed broccoli/cauliflower is about three times the price of untrimmed one. Nevertheless, farmers ship the produce untrimmed to avoid labor costs involved in the trimming process.

Given this situation, trimming and packaging at the harvest site will prolong the freshness-keeping period, prevent physical damages, and in the end enable the produce to attain market positioning as a higher-value product. With this regard, stable business with an institutional buyer has significant importance in realizing it.

Table 2-2-2 Farm-gate Prices of Broccoli

With leaves	40 – 45 pesos/kg
With stem	60 pesos/kg
Floret cluster only (mushroom cut)	120 pesos/kg

Source: Interviews with broccoli growers in Benguet

2) Needs of freshness preservation

Broccoli and cauliflower have a very short shelf life by nature. For their very high physiological activity, broccoli and cauliflower lose the commercial value rapidly; they keep for at most five days after harvesting even when refrigerated.

It takes two days for harvested broccoli and cauliflower to reach the consumer market under the current practice, which lefts three days only to sell the produce in store. Wrapping the whole piece of broccoli/cauliflower with PVC film upon arrival in the store is a wide practice in the supermarkets as means to keep good appearance for a longer period of time. With a longer shelf life, sales opportunities and profitability would increase.

Practically, buyers at the trading post reject broccoli/cauliflower which has lost freshness. Similar selection is made at the secondary distribution level where distributors buy the produce from the buyer. Final consumers also avoid deteriorated ones when they purchase broccoli/cauliflower.

Accordingly, extending the freshness-keeping time period is a prevalent and significant need throughout the distribution process of broccoli/cauliflower.

3) Post-harvest handling in Japan

The table below shows freshness preservation methods for broccoli and cauliflower applied in Japan and intended effects of the methods.

Table 2-2-3 Japanese Practices for Freshness Preservation of Broccoli and Cauliflower

Method	Intended effect
1) Pre-cooling and low-temperature storage and distribution	Reduced respiration (reduced sugar consumption)
	Reduced ethylene production and reduced ethylene sensitivity
	Reduced transpiration
2) Packaging/covering with a film	Reduced transpiration
	Reduced respiration due to lower oxygen concentration (valid when the low-temperature storage/distribution is unavailable; effect is less significant under low temperatures)
	Prevention of damages during transportation and handling
3) Appropriate transport packaging and appropriate way of packing - Vertical or horizontal orientation of the contents - Practice of trimming in the production site - Adjustment of the content volume (number of pieces)	Prevention of damages during transportation and handling
4) Use of freshness-keeping agent - Deoxidizer, carbon dioxide absorber, and activated carbon freshness-keeping agent	

Source: Prepared by the JICA Project Team

As broccoli and cauliflower are floret vegetables that have fastest respiration rates, first consideration should be how to suppress respiration and energy consumption.

Preliminary experiments conducted on broccoli by the PTD observed significant freshness-keeping effects of low temperature and film packaging as shown below.

Table 2-2-4 Freshness-keeping Days of Broccoli under Different Conditions

	Without packaging	With film packaging
Ambient temperature	2 days	3 days
15℃ Chamber	3 days	6 days
1℃ Refrigerator	8 days	30 days

Source: Results of experiments conducted in August 2015

Drawn from the results of above experiments, a conclusive fact is that pre-cooling and low-temperature storage/distribution is the most effective freshness preservation measure. In the Philippines, however, neither pre-cooling facilities in the production area nor cold chain system for distribution has been fully established by now. Accordingly, film packaging is proposed here as a second-best freshness-keeping measure.

4) Subjects of post-harvest process improvement and packaging development

Based on the discussion above, following examines (1) measures to reduce physical damages and quality deterioration during the period/process of delivering the produce from the production area to the consumer, and (2) packaging methods to prolong the freshness-keeping period of broccoli and cauliflower, without assuming pre-cooling in the production area or low-temperature distribution.

2.2.2 Development of Transport Packaging to Reduce Damages during Transportation

(1) Factors affecting damages caused in the transportation process as identified through preliminary experiments

Plastic crates are common as transport containers throughout the broccoli/cauliflower distribution system in Japan. Water-resistant corrugated boxes are also popular for low-temperature transportation by covering the produce with ice.

On the other hand, bamboo baskets and big PE bags are prevalent in the Philippines and as many pieces of broccolis/cauliflowers as possible are crammed randomly inside. Compression due to the tight squeeze is supposed to be a cause of damage to the produce.

Simultaneously, the practice of wrapping the floret cluster with leaves is blamed for poor efficiency of transportation, while being a widespread method of protecting individual pieces of broccoli/cauliflower.

The preliminary experiments quantitatively evaluated the abovementioned problems from the viewpoint of reducing damages and improving transport efficiency.

1) Damages caused under current practice of transport packaging

The actual situation was verified about damages caused in the current practice of transporting broccoli randomly packed in a PE bag or a reused corrugated box. As shown in Table 2-2-5, reused corrugated boxes recorded slightly less severe damages, while 46% of the content was evaluated as rejectable in both packaging conditions. Interviews with farmers also revealed the rejects amounted 40-60% of the produce shipped in a bamboo basket that is generally used by farmers. In comparison, the case of single-layered vertical placement in a corrugated box caused no damage of rejectable severity. That implies compression inside the over-stuffed container is the primary cause for mechanical damages reproduced in this experiments.

Table 2-2-5 Physical Damages in Current Practices (Trimmed broccoli)

	% in pieces		
	With no damage or damages smaller than φ10mm	With damages smaller than φ20mm	With damages φ20mm and larger (not acceptable)
PE bag (random placement)	28	26	46
Reuse corrugated box (random placement)	37	16	46
Corrugated box w/ PE bag inside (single-layered vertical placement)	67	33	0

Note: Field trial (transportation of the sample broccolis on 10-ton truck from the trading post in La Trinidad, Benguet, to Balintawak Wholesale Market in Metro Manila) conducted on February 2, 2016, which was one day after harvesting.

2) Inefficiency in loading leaf-wrapped broccolis/cauliflowers

It was observed that 42 pieces of leaf-wrapped broccolis were contained in a PE bag for transportation while 65 pieces of trimmed (mushroom-cut) broccolis were contained in a same-sized PE bag, as shown in Table 2-2-6. In other words, a leaf-wrapped piece of broccoli required 1.55 times as much space as a mushroom-cut piece did.

The bags of leaf-wrapped and mushroom-cut broccolis weighed 26kg and 21kg respectively, and the weight per piece was calculated as 0.62kg/piece for leaf-wrapped and 0.32kg/piece for mushroom-cut broccolis. Transporting leaf-wrapped broccolis, therefore, is similar to carrying waste almost as heavy as the valuable product itself.

Table 2-2-6 Transport Efficiency (Broccoli in big PE bag)

	Number of pieces in a bag	Gross weight before transportation(kg)	Weight per piece (kg)
Leaf-wrapped (a)	42	26	0.62
Trimmed (b)	65	21	0.32
Ratio (b/a)	1.55	0.81	0.52

Note: Observed at La Trinidad Trading Post in Benguet on February 2, 2016, which was one day after harvesting.

3) Damages caused under different placement methods

Table 2-2-7 summarizes that rejects after transportation amounted 46% of broccolis placed randomly in a reused corrugated box, while the rate dropped to 37% with the double-layered horizontal placement. Further, no reject was caused in broccolis transported by single-layered vertical placement in a corrugated box. The space efficiency of transport packaging, however, decreased accordingly.

Table 2-2-7 Difference in Damages by Placement Method (Trimmed broccoli)

	% in pieces		
	With no damage or damages smaller than φ10mm	With damages smaller than φ20mm	With damages φ20mm and larger (not acceptable)
Random placement in reused corrugated box	37	16	46
Double-layered horizontal placement in corrugated box	42	21	37
Single-layered vertical placement in corrugated box (with big PE bag inside)	67	33	0

Note: Field trial (transportation of the sample broccolis on 10-ton truck from the trading post in La Trinidad, Benguet, to Balintawak Wholesale Market in Metro Manila) conducted on February 2, 2016, which was one day after harvesting.

4) Damage-reducing effects of individual packaging

With double-layered horizontal placement, individually film-packaged broccolis received approximately 30% less damages of rejectable levels, as compared to the ones without individual packaging. Broccolis placed vertically without layering in the box were free from rejectable-level damages even when individual packaging was not applied.

Table 2-2-8 Reduction of Damages in Transportation Process with use of Individual Film Packaging (Trimmed broccoli, Double-layered horizontal placement)

	% in pieces		
	With no damage or damages smaller than φ10mm	With damages smaller than φ20mm	With damages φ20mm and larger (not acceptable)
With individual film packaging (sealed LDPE pouch)	61	13	26
Without individual packaging	42	21	37
Single-layered vertical placement in corrugated box (with big PE bag inside)	67	33	0

Note: Field trial (transportation of the sample broccolis on 10-ton truck from the trading post in La Trinidad, Benguet, to Balintawak Wholesale Market in Metro Manila) conducted on February 2, 2016, which was one day after harvesting.

(2) Proposed methods of transport packaging

Based on the results of preliminary experiments discussed above, the following improvements are recommended for post-harvest handling and transportation in order to prevent damages during transportation and preserve freshness of broccoli/cauliflower.

1) Abandon the leaf-wrapping practice and prepare broccolis/cauliflowers in the mushroom-cut shape;
2) Apply individual film packaging as early as possible after harvesting, desirably in the production area;
3) Avoid over-stuffing and compression by replacing bamboo baskets and PE bags with plastic crates and corrugated boxes as transport packaging;
4) Improve the method of placement in the container, specifically adopting the single-layered vertical placement or the double-layered horizontal placement inside a large film bag overlaid in the container;
5) Fill the bottom of the container with crumpled newspapers to alleviate shocks during transportation; and
6) Apply individual film packaging after arrival in the trading post and use corrugated boxes (or plastic crates when a returning system is established) for transportation thereafter.

Individual film packaging, which is expected to have freshness-keeping effects (as discussed in 2.2.2) as well as damage-preventing effects (2.2.3-(1)-4), may preferably be applied as the farm-level preparation before shipment. Practically, however, it is difficult to overcome the constraints on facilities, man power, skills, and other resources in the near future. Therefore the recommendation above assumes individual packaging be applied at the trading post or in the consuming area.

Introducing plastic crates involves development of a returning system. Besides, the crates should be collapsible to minimize the cost of return transport. Corrugated boxes may be promoted as the temporary substitute which saves the returning cost before the time when the returning system is established and collapsible crates are adopted widely. Returnable plastic crates are more recommendable nevertheless from the environmental viewpoint.

(3) Verification of effectiveness

Proposed transport packaging methods were verified through field trials. For broccoli, a significant damage-reducing effect of crumpled newspaper cushion was observed regardless of the container type and placement method. For cauliflower, damages were lessened as the placement method was changed from random to double-layered horizontal to single-layered vertical arrangements, as observed for broccoli in the preliminary experiments. Crumpled newspaper cushion was also effective for cauliflower across different container types and placement methods.

Trials using Super Green Pack EG[1] showed good results for damage reduction and freshness preservation. The results were estimated to be brought by a combination of effects of the following factors:

- The placement method (single-layered vertical placement) and film packaging had damage-reducing effects;
- Group packaging with a big PE bag had freshness-keeping effects, especially transpiration-restraining effects; and
- The chemical agent had freshness-keeping effects, by creating low O_2 and high CO_2 concentration inside the PE bag (a form of MA packaging).

[1] Super Green Pack EG is a product of a Japanese packaging company, Rengo Co. Ltd., which combines a corrugated box, a PE bag overlaid inside the box, and a pouch of freshness-keeping agent placed in the bag to give superior freshness preservation effects on green vegetables. It is marketed only in Japan as of March 2017.

Table 2-2-9 Damages by Packaging and Placement Method

	Number of pieces in a package	ΔDamage score	ΔDamage score per piece
Trimmed broccoli			
Plastic crate with cover (random placement)	24	-58	-2.42
Plastic crate with cover and crumpled newspaper cushioning (random placement)	24	-21	-0.88
Plastic crate with cover (double-layered horizontal placement)	24	-73	-3.04
Plastic crate with cover and crumpled newspaper cushioning (double-layered horizontal placement)	24	-33	-1.38
Corrugated box (double-layered horizontal placement)	24	-114	-4.75
Corrugated box with crumpled newspaper cushioning (double-layered horizontal placement)	24	-24	-1.00
Trimmed cauliflower			
PE bag (random placement)	50	-262	-5.24
Plastic crate with cover (random placement)	50	-387	-7.74
Plastic crate with cover and crumpled newspaper cushioning (random placement)	50	-306	-6.12
Plastic crate with cover and crumpled newspaper cushioning (double-layered horizontal placement)	28	-143	-5.11
Corrugated box with big PE bag inside (single-layered vertical placement)	30	-74	-2.47

Note: Field trial (transportation of the sample broccoli/cauliflower on 10-ton truck from the trading post in La Trinidad, Benguet, to Balintawak Wholesale Market in Metro Manila) conducted on May 4, 2016 on broccoli and December 3, 2016 on cauliflower, both of which were one day after harvesting.
Damage score is obtained by adding up the points given to all the damaged parts observed before and after transportation according to the size range: smaller than φ10mm (-1), smaller than φ20mm (-2), smaller than φ30mm (-3), and φ30mm or larger (-4).

(4) Assessment of viability of the proposed technology and method

With improvement of transportation efficiency by trimming the produce at the early stage of distribution after harvest, and by preventing damage on the trimmed produce, the sales revenue less increased costs & expenses will be increased by 240% (or from P. 14.3/pcs to P. 34.4/pcs).

For detail, see Table 2-2-10.

Table 2-2-10: Expected Economic Effects of Application of the Proposed Technology/Method

Broccoli (2)

Improvement of transportation efficiency with conduct of product trimming at the early stage of distribution after harvest, and prevention of damages of the trimmed product during transportation

➡ **Effect:** 1) Reduction of loss due to the damage during transportation, and 2) saving of transportation cost with increased transportation efficiency

Practice/ actions	Revenue and costs/expenditure		Per kg			Amount/pcs (Pesos/pcs)	Basis of the revenue/costs/expenditures estimate
			Volume	Unit price	Amount (per Jeepney)		
Current practice	Sales	Shipment	660	40	26,400	24.7	12 baskets/Jeepney x 55kg/basket = 660kg/Jeepney; or 12 baskets x 89 pcs/basket (leaf-wrapped @620g/pcs) = 1,068 pcs/Jeepney; Loss due to damage during transportation 40% (Salable volume: 660kg x 0.6=396 kg, or 639 pcs)
		Loss	-264	40	-10,560	-9.9	
		Net sales	396	40	15,840	14.8	
Transportation in PE bag with random placement of leaf-wrapped broccoli	Costs & expenses	Basket	12	1.2	14.4	0.0	Unit price of the basket 120/pcs; Durability (times of use) 100 times; Cost of basket /use P.1.2/use)
		Freight of Jeepney	1	550	550	0.5	One way only (free for return trip)
		Sub-total (*2)			564	0.5	
	Balance (*1)				15,276	14.3	Shipment: 1,068pcs/Jeepney
Proposed practice	Sales	Shipment	230	120	27,600	38.3	60 crates/Jeepney x 12pcs/crate x 0.320kgs/pc (mushroom-cut @320g/pcs) = 230kg/Jeepney; or 60 crates x 12 pcs/crate = 720 pcs/Jeepney; Loss due to damage during transportation 0% (Salable volume: 230 kg, or 720 pcs)
		Loss	0	120	0	-	
		Net sales	230	120	27,600	38.3	
Transportation in plastic crate with vertical placement in 1 layer of trimmed (mushroom cut) broccoli	Costs & expenses	Crate	60	29	1,740	2.4	Unit price of the crate P.570/crate; Durability (times of use) 5 years x 4 times/year; Cost of basket /use P.570/20 times of use = P.29/use)
		Freight of Jeepney	2	550	1,100	1.5	Round trip
		Sub-total (*2)			2,840	3.9	
	Balance (*1)				24,760	34.4	Shipment: 720pcs/Jeepney

▼Increase in profit/increase in required investment (Δ*1/Δ*2): (24,760-15,276)/(2,840-564)=4.2

2.2.3 Development of Freshness Preservation Packaging

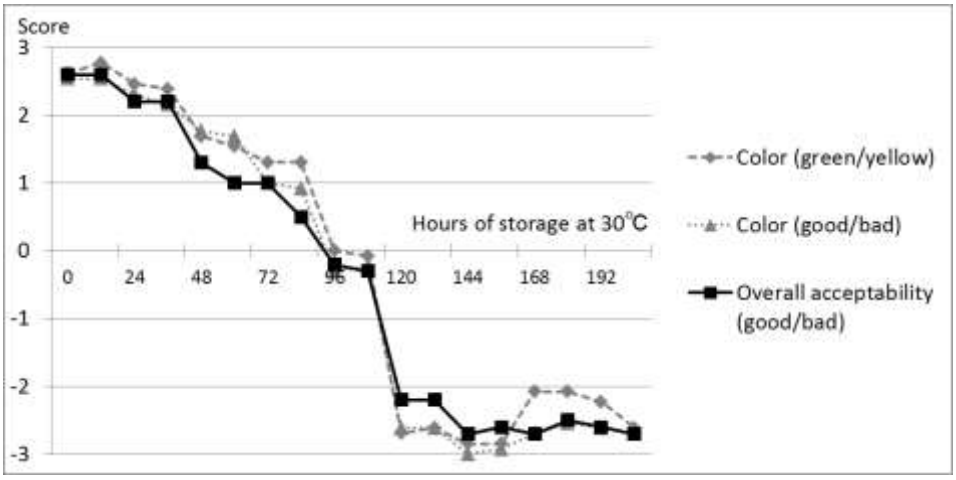
(1) Factors affecting freshness deterioration as identified through preliminary experiments

Major causes for freshness deterioration of broccoli and cauliflower are known to be [1] wilting through transpiration and [2] opening or yellowing of florets through respiration. The preliminary experiments confirmed the generally-accepted theory and examined possibility of restraining transpiration and respiration by applying film packaging.

1) Indicators of freshness deterioration

Yellowing or discoloration of the floret cluster was the most decisive indicator of losing freshness for both broccoli and cauliflower in the consumer's eyes, according to the sensory tests to determine the end of commercial value after harvested. The panel responses showed that the decision to buy a piece of broccoli/cauliflower depended largely on the color of floret cluster which was the earliest-surfacing indicator of quality deterioration.

Therefore, the end of commercial value when stored at an ambient temperature was determined based on tolerance limit for yellowing/discoloration as 5 days and 6 days after harvesting for broccoli and cauliflower, respectively.



Note: Tests conducted in February 2016. The panel evaluated every factor by using a 7-grade scoring system that ranges from very good (3) to very bad (-3) for good/bad evaluation, or fully green (3) to fully yellow (-3) for green/yellow evaluation. The graph shows the mean scores.

Figure 2-2-2 Sensory Evaluation of Color and Overall Acceptability on Broccoli over Time

Table 2-2-11 Sensory Evaluation of Quality Factors of Cauliflower over Time

Days after harvesting	Luster	Color	Smell	Texture	Taste	Overall acceptability
2 days	2.25	2.00	2.25	2.00	2.25	2.25
3 days	2.00	1.50	2.25	2.00	2.25	2.25
4 days	2.00	1.25	2.25	2.00	2.25	2.25
5 days	1.75	0.50	1.75	2.00	2.00	1.50
6 days	1.70	-0.75	1.25	2.00	1.50	1.50
7 days	1.70	-1.00	1.25	2.00	0.75	0.85
8 days	0.20	-1.50	0.75	2.00	0.35	0.85

Note: Tests conducted in December 2017. The panel evaluated every factor by using a 7-grade scoring system: very good (3), good (2), slightly good (1), neutral (0), slightly bad (-1), bad (-2), and very bad (-3). The table shows the mean scores.

2) Effectiveness of film packaging against transpiration

Film packaging was effective in preventing transpiration regardless of the kinds of film (HDPE or OPP). Weight decrease over time was not significant for film-packaged broccoli and cauliflower, while broccoli and cauliflower without packaging decreased the weight by 30% or 20% in 60 hours, respectively, at 30℃.

Low temperature was effective in suppressing transpiration even without packaging. Weight loss in 60 hours under 13℃ was 15% for broccoli and 10% for cauliflower without packaging, which was much less than the figure at 30℃.

In addition, transpiration of cauliflower was less significant compared to that of broccoli.

Table 2-2-12 Weight Change of Broccoli and Cauliflower in 60 Hours

		30℃	13℃
Without packaging	Broccoli	Decrease by 30%	Decrease by 15%
	Cauliflower	Decrease by 20%	Decrease by 10%+
Anti-fogging OPP (T 30μm) with φ6mm holes	Broccoli	No significant change	No change
	Cauliflower	No significant change	No change
Anti-fogging OPP (T 30μm) sealed	Broccoli	No significant change	No change
	Cauliflower	No significant change	No change
HDPE (T 15μm) sealed	Broccoli	No significant change	No change
	Cauliflower	No significant change	No change

Note: Experiment conducted in November 2015

3) Effectiveness of film packaging against respiration

The modified atmosphere (MA) condition was achieved with sealed HDPE film packaging for both broccoli and cauliflower and delayed yellowing or discoloration by two days regardless of the temperature. Change in the concentration of oxygen and carbon dioxide is faster at the ambient temperature (30℃) than at lower temperatures.

Table 2-2-13 Gas Concentration and Yellowing/Discoloration of Broccoli and Cauliflower

		O2 concentration	CO2 concentration	Start of yellowing / discoloration
30℃				
Without packaging	Broccoli	N.A.(atmospheric air)		in 20 hours
	Cauliflower			in 42 hours
Anti-fogging OPP (T 30μm) with φ6mm holes	Broccoli	N.A. (atmospheric air)		on 4th day
	Cauliflower			(No observation)
Anti-fogging OPP (T 30μm) sealed	Broccoli	0% in 20 hours	Sharp increase	Smell of fermentation before yellowing
	Cauliflower	0% in 20 hours	Sharp increase	(No observation)
HDPE (T 15μm) sealed	Broccoli	Equilibrate at 50% in 20 hours	Equilibrate immediately	on 6th day
	Cauliflower	Equilibrate at 50% in 20 hours	Equilibrate immediately	(No observation)
13℃				
Without packaging	Broccoli	N.A.(atmospheric air)		Evident on 6th day
	Cauliflower			(No observation)
Anti-fogging OPP (T 30μm) with φ6mm holes	Broccoli	N.A. (atmospheric air)		Evident on 6th day
	Cauliflower			(No observation)
Anti-fogging OPP (T 30μm) sealed	Broccoli	0% in 40 hours	Sharp increase	Smell of fermentation before yellowing
	Cauliflower	0% in 40 hours	Sharp increase	(No observation)
HDPE (T 15μm) sealed	Broccoli	Equilibrate at 50% in 40 hours	Equilibrate immediately	Slight yellowing started on 6th day
	Cauliflower	Equilibrate at 75-80% in 20 hours	Equilibrate immediately	(No observation)

Note: N.A.: Not applicable
Experiment conducted in November 2015. Time lapse measured from the start of experiment (application of packaging).

Leveraging the nature of fresh fruits and vegetables that respiration is suppressed under reduced oxygen concentration, the MA packaging is a method to restrain respiration by limiting oxygen influx with film packaging and thus lowering oxygen

concentration inside the package. With successful MA packaging, the respiration rate of the fruit/vegetable and the gas transmission rate of the package come to equilibrate and the oxygen concentration stabilizes at a certain level which should be lower than that of the atmospheric air (21%) and higher than 2% (to avoid anaerobic respiration).

4) Harmful effects of oxygen deficiency

The respiration rate of broccoli and cauliflower is quite high and use of OPP film packaging without holes resulted in an anaerobic condition or high carbon dioxide concentration within a short period of time. Foul odor of broccoli caused by fermentation was observed after 20 hours at 30℃ and 40 hours at 13℃ before yellowing or discoloration. Yellowing or discoloration was a sign of losing freshness which broccolis without packaging showed on the fourth day at 30℃ and on the sixth day at 13℃. Further deterioration under the anaerobic condition or high carbon dioxide concentration resulted in decay, stench, molds, browning, and gooey.

Balancing the gas transmission rate and the respiration rate is the key to avoid these harms.

Table 2-2-14 Gas Concentration and Smell/Odor of Broccoli and Cauliflower

		O2 concentration	CO2 concentration	Smell / Odor
30℃				
Anti-fogging OPP (T 30μm) sealed	Broccoli	0% in 20 hours	Sharp increase	Foul odor in 20 hours
	Cauliflower	0% in 20 hours	Sharp increase	Foul odor in 26 hours
HDPE (T 15μm) sealed	Broccoli	Equilibrate at 50% in 20 hours	Equilibrate immediately	Normal smell of the vegetable
	Cauliflower	Equilibrate at 50% in 20 hours	Equilibrate immediately	Normal smell of the vegetable
13℃				
Anti-fogging OPP (T 30μm) sealed	Broccoli	0% in 40 hours	Sharp increase	Foul odor in 40 hours
	Cauliflower	0% in 40 hours	Sharp increase	Foul odor in 40 hours
HDPE (T 15μm) sealed	Broccoli	Equilibrate at 50% in 40 hours	Equilibrate immediately	Normal smell of the vegetable
	Cauliflower	Equilibrate at 75-80% in 20 hours	Equilibrate immediately	Normal smell of the vegetable

Note: Experiment conducted in November 2015. Time lapse measured from the start of experiment (application of packaging).

In sum, results of the preliminary experiments suggest that application of appropriate film packaging will defer yellowing or discoloration by two days from what is otherwise four (30℃) or six (13℃) days after harvesting, by suppressing transpiration and creating an MA condition that reduces respiration. The method is expected to be effective for both broccoli and cauliflower alike.

In addition, film properties other than gas permeability should be taken into consideration so that the packaging to be developed will suit for commercial use. Specifically, adequate transparency to give a good vision of the content and sufficient firmness to hold the shape of package are desirable properties in this regard. Recommended is micro-perforated OPP film.

(2) Proposed methods of freshness preservation packaging

Based on the results of preliminary experiments discussed above, the following measures are recommended for preserving freshness and prolong fresh-keeping period of broccoli/cauliflower.

1. Apply film packaging which is designed to induce MA effects without causing an anaerobic condition; and
2. Use a type of film which possesses transparency and firmness to meet requirements for consumer packaging.

1) Proposed specification of freshness preservation packaging

Recommended specification of film packaging for preserving freshness of broccoli and cauliflower is as follows.

Table 2-2-15 Specification of Proposed Film Packaging

Material	Anti-fogging OPP (T 20μm)
Pouch	Size: W 200mm x D 300mm - Perforate 8 tiny holes (φ150μm) evenly dispersed on the surface - Heat-seal the opening
Content quantity	1 piece/pouch

2) Expected effects

With the proposed packaging applied, broccoli and cauliflower will keep its freshness for some two days longer than without packaging. The produce will be prevented also from wilting or losing weight for transpiration.

Significant effects of freshness preservation can be achieved even without packaging, once the infrastructure is in place and pre-cooling in the production area and low-temperature storage/distribution thereafter is made possible. Use of film packaging under cold-chain distribution systems will give additional effectiveness.

(3) Verification of effectiveness

Verification tests targeted an air-conditioned room temperature, assuming commercial use of the proposed packaging at supermarkets. Samples packaged in a 20μm-thick LLDPE pouch, which has the oxygen transmission rate same as the HDPE pouch previously verified for a good MA effect, are also tested as a reference model. The LLDPE film provides better visibility of the content compared to the HDPE film.

The proposed packaging with a 20μm-thick anti-fogging OPP film pouch with eight tiny holes dispersed on the surface successfully created an MA condition for both broccoli and cauliflower at the temperatures of 22℃. The oxygen concentration in the pouch came to stability at around 10-13% and the freshness-keeping period was extended by two days for both vegetables. Table 2-2-16 summarizes the results.

Table 2-2-16 Effectiveness of Proposed Freshness Preservation Packaging at 22℃

		Weight change (Day 6)	O2 concentration	Yellowing / Discoloration
Proposed packaging (Anti-fogging OPP [T 20μm] with 8 φ150μm holes)	Broccoli	No change (less than 1 %)	Equilibrate at 10%	No yellowing/browning until Day 5
	Cauliflower	No change (less than 1 %)	Equilibrate at 13%	No yellowing/browning until Day 5
Reference model (LLDPE [T 20μm])	Broccoli	No change (less than 1 %)	Equilibrate at 8-10%	No yellowing/browning until Day 4
	Cauliflower	No change (less than 1 %)	Equilibrate at 10%	No yellowing/browning until Day 5
Control (without packaging)	Broccoli	Decrease by 20%+	(atmospheric air)	Noticeable on Day 3; Full brown/yellow Day 6
	Cauliflower	Decrease by 15%	(atmospheric air)	Noticeable on Day 4

Note: Experiment conducted in December 2016. The date of harvest was set as Day 0.

(4) Assessment of viability of the proposed technology and method

With application of film packaging which can prolong the shelf-life of the produce by use of modified atmosphere packaging (MAP), loss of unsold produce due to rapid quality deterioration in the case without packaging, and/or opportunity loss due to price decrease thereof, can be reduced.

If the unsold loss of 15% of total sales amount at the sale price P. 120/kg (in the case of trimmed broccoli) can be eliminated, by prolonging the shelf-life by 2 days with use of the proposed film packaging, the sales amount will be increased by 15.7% (or by P. 894/55kg (the volume contained in a basket under the current practice)).

For detail, see Table 2-2-17.

Table 2-2-17: Expected Economic Effects of Application of the Proposed Technology/Method

Broccoli (1)

Prolonged shelf-life with MAP

➡ **Effect:** Reduction of unsold loss of 15% of total sales amount with prolong shelf-life

Practice/ actions	Revenue and costs/expenditure						Basis of the revenue/costs/expenditures estimate
			Per kg			Amount/55kg (or Amount/basket)	
			Volume	Unit price	Amount		
Current practice Without MAP (Trimmed product, no damage during transport and handling is assumed)	Sales	Shipment	1.00	120	120	6,600	Sales price at the farm gate
		Unsold loss	0.15	120	18	990	
		Net sales			102	5,610	
	Costs & expenses		0	0	0	0	
		Sub-total			0	0	
	Balance (*1)				102	5,610	
Proposed practice Use of MAP (Trimmed product, no damage during transport and handling is assumed)	Sales	Shipment	1.00	120	120	6,600	
		Unsold loss	0.0	120	0	0	
		Net sales			120	6,600	
	Costs & expenses	Film pouch for MAP	3.7	0.47	2	96	270g/pouch (3.7 pouches/kg)
		Sub-total			2	96	
	Balance (*1)				118	6,504	

▼Increase in profit/increase in required investment (Δ*1/Δ*2): (6,504-5,610)/(96-0)=9.3

2.2.4 Remaining Issues and Recommendations

(1) Fine-tuning the number of holes on film pouches for better freshness preservation effects

The verification tests on the proposed freshness preservation packaging proved effectiveness of the perforated OPP film pouch with eight holes. Nevertheless, room of improvement remains; the oxygen concentration at the equilibrium, which can be as low as 5% to obtain the maximum MA effect, was around 10-13% at an air-conditioned room temperature (22℃) assimilating to supermarket sales floors.

Pouches with a smaller number of holes may bring better freshness-keeping effects, while a safety allowance is needed to accept fluctuations by cultivar, production site, and season. Further trials will fine-tune the developed method.

(2) Reduction of the time period from harvesting to delivering to the retailer

Once the use of wilted foliage as protection is abandoned, the time length which has been required for the practice (i.e. hang the produce outside after harvesting, wrapping the floret cluster one by one and re-doing it at the trading post) can be eliminated by setting an appropriate harvesting time that deliver the produce just in time for trucking at the trading post.

That way broccoli and cauliflower from Benguet arriving in the retail market will be fresher, better quality, and thus of higher value to the consumer.

(3) Pre-cooling, pre-packaging and refrigerated transportation

Low temperature is more direct and important in restraining respiration of fresh fruits and vegetables than reduced oxygen concentration. The sooner the produce is cooled after harvesting, the more effectively its freshness will be preserved. The developed MA packaging will preserve more freshness when applied earlier in the distribution process. Note that the temperature must be kept constant after packaging.

Investment in pre-cooling and packaging facilities in the production area should be considered for a greater improvement of quality to the consumer.

2.3 Durian

2.3.1 Current Practice and Needs for Improved Post-harvest Handling and Packaging Technologies

(1) Current post-harvest and distribution practice

Durian is sold either in whole fresh, frozen flesh, or such processed products as jams, candies and chips, etc. With pericarp being 50-60% of weight of the fruit, frozen flesh is gaining popularity particularly among the consumers in remote markets and visitors.

The following outlines the current post-harvest and distribution practice.

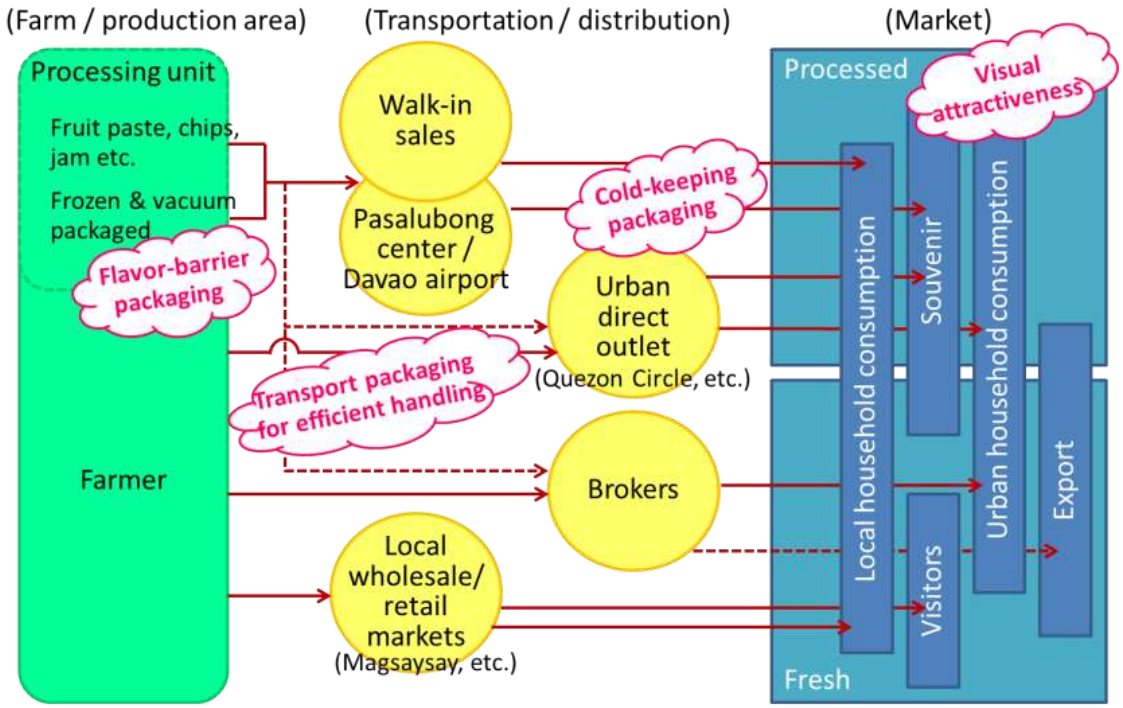
Table 2-3-1 Current Post-harvest and Distribution Practices of Durian

Current practice			Remarks
Immediate after harvest		Stored in bulk	Without any packaging/ containers
Local transport (from farm to local retail shops)		In bulk	Loaded in bulk directly on pick-up van, etc., without any packaging/ containers
Initial treatment/ processing (for frozen durian)		Take out the flesh from the husk, package it into smaller sizes, and freeze	Objective of frozen product: 1) Alleviate depressed market prices of fresh durian in the season due to concentration of harvest timing in a short period 2) Increase convenience in handling, by withholding the strong aroma, reducing the transport volume, and providing ready-to-eat easiness.
Transport and distribution	Fresh durian	1) In bulk or in wooden crate	
		2) Corrugated box with aeration holes	To reduce damage on the fruit (to be caused by insufficient aeration, mechanical shock, or vibration)
	Frozen durian	EPS box	To keep the product frozen during transportation (to the retail store)
For handling by consumers	Frozen durian	EPS carry-out box	Keep the product frozen until the consumer gets home

Source: Prepared based on the results from field survey conducted in April 2013 in Davao

(2) Distribution channels of durian from Davao and emerging packaging needs

Figure 2-3-1 illustrates the current distribution pattern of durian from Davao and emerging needs for packaging development in different levels of the distribution process.



Source: Prepared based on interviews conducted in April 2013 with durian growers in Davao

Figure 2-3-1 Distribution of Durian and Emerging Needs

(3) Issues and needs of improvement in the post-harvest and distribution process of durian

1) Freezing and packing of frozen durian

Durian flesh is taken out from husk and frozen in small pouch or tray. Current practice in the freezing and packaging process and the needs for improvement in the practice are as shown in Table 2-3-2. While freezing is a good way to suppress the strong aroma, the aroma resumes as once frozen durian is thawed. Even while durian is kept frozen, the aroma can migrate to other foods in the freezer.

Table 2-3-2 Current Practice of Freezing and Packaging Durian and Needs for Improvement

Current practice	Objective of the practice	Needs of improvement related to the practice
1) Durian flesh is taken out from husk, and 2) Packed in small-size packaging using plastic wrap, pouch, tray, and/or container 3) Kept in freezer or EPS box	1) To preserve the product longer and avoid to sell it at depressed market prices in the season 2) To provide easiness of handling and eating 3) To reduce the strong aroma during storage and hand-carrying	1) Improvement of the flavor-barrier properties for the consumer to be able to carry it without restriction 2) Improvement of packaging operation to prevent the pouch of frozen durian from defect packaging

Source: Prepared based on interviews conducted in April 2013 with durian processors in Davao

Frozen durian double-packaged with wrap film and a pouch (left) as an improvement from conventional frozen durian packaged in a polystyrene container (right)

Frozen durian packaged
in a polystyrene container

2) Transportation of frozen durian

There are two phases of transportation process, which require appropriate measures to keep the durian frozen. Current practice of transporting frozen durian and the needs of improvement related to the practice are as shown in Table 2-3-3.

Current carrying box, which is an EPS box without a handle, is bulky compared to the content and inconvenient for the consumer to carry around with.

EPS boxes currently used for bulk transportation of frozen durian require space even when they are not used for the purpose of transportation. Further, it is difficult to obtain an EPS box of exact form and size for a certain quantity of the product, which undermines the cold-keeping capacity of the container. A collapsible corrugated box can be a better substitute as long as it provides equivalent heat insulation.

Table 2-3-3 Current Practice of Transporting Frozen Durian and Needs for Improvement

Current practice	Objective of the practice	Needs of improvement related to the practice
For transportation of frozen durian, following packages are used to keep the product frozen: 1) Hand-carry EPS box for consumers 2) EPS box for distribution	1) Carrying out by consumers 2) Long-distance transport by distributors	1) Improve efficiency and attractiveness of hand-carrying box 2) Increase in the cold-keeping capacity to meet requirements by destination

Source: Prepared based on interviews conducted in April 2013 with durian growers and traders in Davao

Hand-carrying box (1) Ice Cream Box
40 times expanded EPS foam box
L230 × W230 × H175mm, T: 12mm

Hand-carrying box (2): Fillet Box
40 times expanded EPS foam box
L320 × W200 × H140mm, T: 20mm

Bulk transport package: Super Box (contains 50 packs/box, GW: 27 kg)
40 times expanded EPS foam box L400 × W400 × H420mm, T: 20mm

3) Transportation of fresh durian

In the case of local transportation in the production areas, fresh durian is loaded on truck either in bulk or packed in wood container. Corrugated box is used for transportation to distance markets or exports. Current practice of transporting fresh durian and the needs for improvement related to the practice are shown in Table 2-3-4.

Table 2-3-4 Current Practice of Transporting Fresh Durian and Needs for Improvement

Current practice	Objective of the practice	Needs of improvement related to the practice
Use of Corrugated box with aeration holes for long distance transport and exports	To prevent fresh durian from damages due to mechanical shock and vibration, and insufficient aeration in the transportation process	Device against damages on the box because of the fruit having heavy and hard husk
No packaging/container or use of wooden container		Loss from farm to retail is about 15% (moisture/ weight loss) and another 5% loss attributed to spoilage (cracking, etc.)

Source: Prepared based on interviews conducted in April 2013 with durian growers and traders in Davao

BC flute corrugated fiberboard box with cross partition
Internal dimension: L400xW400xH420 Content: fresh durian 4 pcs/box Gross weight: 13 kg


Fact-finding field trials revealed that the current transport packaging did not satisfy the strength required for efficient handling of heavy load. After transportation from Davao to Manila, hand holes provided on the side panels of transport container were broken and the fruit had swung and shifted to change the orientation inside the container.

4) Marketing promotional functions of packaging for frozen and fresh durian

The series of durian packages lacks an unified image which is necessary to establish brand recognition. Hand-carrying boxes for frozen durian as well as transport packaging for fresh whole durian does not have any graphic design applied, which miss the opportunity to promote the product in the market. Furthermore, when a new flavor-keeping packaging technology is developed and introduced, there will be a need to visually present the benefits of the technology to promote adoption. The carrying box, as well as the flexible individual package, will be part of the communication media.

(4) Proposed improvement of post-harvest practice and packaging development

The following are the proposed improvement of post-harvest practice and packaging development under the current project, derived from the needs discussed above.

1. Development of flavor-barrier packaging for frozen durian flesh
2. Extension of frozen storage capacity of hand carrying box and transport container of the frozen durian flesh
3. Strengthening of transport packaging of fresh whole durian
4. Development of promotional consumer packages to explore/develop untapped consumer markets

2.3.2 Development of Flavor-barrier Packaging for Frozen Durian Flesh

(1) Requirements for the packaging to be developed

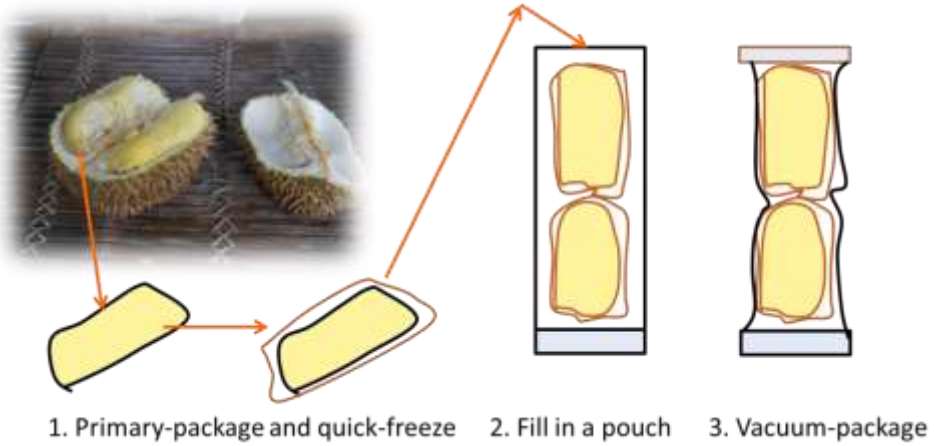
The packaging development is intended for materializing odor-free frozen durian products by packaging durian flesh with materials proven for the high flavor-barrier properties, and thus cultivating the potential demand for durian fruit. Flexible films present varying barrier properties to different flavor compounds and the current packaging development involves identifying a film composition effective for the particular flavor of durian.

At the same time, the packaging materials must be freeze-resistant, since it is used for frozen product.

Further, it should be noted that the flavor-barrier packaging, which allows very low gas permeability, will suit only for frozen storage, because of the fact that the fruit would get translucent in color and change the flavor under the anaerobic condition due to its high rate of respiration.

(2) Proposed specification of the packaging for flavor keeping packaging of frozen durian

The proposed packaging is to apply double-packaging to frozen durian flesh with a wrap film and a film pouch of materials proven for the high flavor-barrier properties, as described in Figure 2-3-2 and Table 2-3-5.



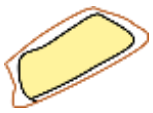
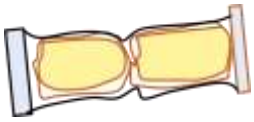
Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

Figure 2-3-2 Proposed Packaging Method for Frozen Durian

Film materials are selected by comparing their flavor barrier properties, strength under frozen temperature, pinhole strength when vacuum-packaged, and total cost of the package. Practically, a pre-existing practice of double-packaging was combining HDPE sheets for primary and ON/LDPE pouches for secondary packaging. Given that any incidents of pinhole had been observed with the ON/LDPE pouch, only adding a barrier material to the current film composition is recommended; specifically, polyvinylidene chloride (PVDC)-coated oriented-nylon (ON), or KON, should replace ON to form KON/LDPE film.

With regards the inner wrap, PVDC was the first candidate for its high barrier properties. However, laboratory tests found that PVDC wrap turned stiff at frozen temperatures and easily cracked and torn. Eventually, KON was recommended for its stability under frozen temperatures as well as the sufficient barrier properties. The method of primary packaging was changed accordingly from twist-wrapping to vacuum-packaging since the KON film is not adsorptive.

Table 2-3-5 Proposed Packaging Materials for Frozen Durian

	For primary packaging	For secondary packaging
		
Requirement	- Provide ready-to-eat convenience without mess of picking out pieces of durian flesh - Primary barrier for durian aroma for the case of one by one consumption	- Powerful barrier to confine the aroma - Provide in the optimum unit volume
Recommended film material	- KON pouch - KON/LLDPE pouch	- KON/LLDPE pouch

Note: KON and KON/LDPE films are not sold in the Philippines as of January 2017, while local converters manufacturing ON/LDPE films can easily expand their product lines to include KON/LDPE once raw material is procured. Inner wrap may be substituted with KON/LDPE, although it would be less easy to tear open.

Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

(3) Verification of effectiveness

Verification tests confirmed that the combination of KON primary packaging and KON/LLDPE secondary packaging was effective for confining the durian aroma, as shown in Table 2-3-6. The primary packaging needs to be vacuum-packed, as rolling the durian flesh with the non-adsorptive KON film and twisting the two ends do not provide stable sealing.

Table 2-3-6 Double-packaging Methods and Migration of Durian Smell

Primary packaging	Secondary packaging (vacuum-packaged)	Smell migration	Observation
Proposed Packaging			
KON (vacuum-packaged)	KON/LLDPE	None	
KON (center heat-sealed, ends twisted)	KON/LLDPE	Slight	
PVDC (ends twisted)	KON/LLDPE	Slight	Cracks in PVDC wrap
Control			
HDPE (ends twisted)	ON/LDPE	Prominent	

Note: Tests conducted in July 2013, December 2013-July 2014, and July 2014-January 2015. Packaged samples were stored frozen (-20℃) for up to 6 months.

Box 2-3-1 Correlation between Barrier Property against Durian Smell and Oxygen Permeability

It is confirmed that the barrier properties against durian aroma and the oxygen permeability of flexible films are closely related. Sensory test results were consistent to the calculated oxygen permeability of double-packaging as shown below.

Oxygen Permeability of Double-Packaging

		Secondary packaging	
		ON/LDPE 80 cc/m^2. 24 hr. atm.	KON/LLDPE 8 cc/m^2. 24 hr. atm.
Primary packaging	HDPE 13,000 cc/m^2. 24 hr. atm.	**79.9 cc/m^2. 24 hr. atm.**	7.99 cc/m^2. 24 hr. atm.
	PVDC 80 cc/m^2. 24 hr. atm.	40 cc/m^2. 24 hr. atm.	**7.27 cc/m^2. 24 hr. atm.**

Note: The oxygen permeability of layered multiple films (P_0) is obtained, given the oxygen permeability of each film (P_1, P_2, … P_n), by applying: $1/P_0 = 1/P_1 + 1/P_2 \ldots + 1/P_n$

Sensory Evaluation of Smell Migration

		Frozen (-20℃)		Chilled (5℃)	
		HDPE + ON/LDPE	PVDC + KON/LLDPE	HDPE + ON/LDPE	PVDC + KON/LLDPE
Storage period (days)	1	1.6	1.2	4.6	1.0
	3	1.3	1.0	4.8	1.0
	6	1.8	1.0	4.4	1.3
	10	1.7	1.4	4.6	1.5

Note: 1- no smell; 2 - slight smell; 3 - moderately strong smell; 4 - strong smell; 5 - very strong smell
The mean scores by the panel of 7 persons are provided.

(4) Expected reduction of loss with application of the proposed packaging

Application of the proposed flavor-keeping package is expected to be effective in solving the following 2 problems:

1) Instability of durian sales (and unsold durian thereof), which has been caused by strong seasonality of harvest of durian

   The problem of the unsold loss of around 15% of the total harvest is expected to be solved with promotional effects of frozen durian with use of the proposed flavor-keeping packaging.
   In addition, the sales price may be expected to be increased with improved frozen durian packaging, from the current price level of around P. 125/kg (the price of frozen durian at the local sales shops) to the price levels of P. 175/kg (the price sold at the airport targeting the visitors).

2) Loss due to price decrease in season, which has been caused by strong seasonality of harvest of durian

   The average price of fresh durian in season is P. 10～30/kg, while it can be sold at P. 25-60/kg after the season. The price of frozen flesh is also expected to be increased after season as in the case of fresh durian.

(5) Assessment of viability of the proposed technology and method

With 1) freezing the durian flesh, and 2) development of flavor keeping package for the frozen flesh, unsold loss of durian, which has been caused by over-supply in the harvest season due to high concentration of harvest in a limited short period, can be reduced because of the prolonged shelf-life of frozen product. In addition, the flavor keeping nature of the packaging will have advantage in marketability and enable it to be sold at the price higher than the prevailing market price.

Assuming that the problem of the unsold loss of around 15% of the total harvest is solved by promotion of frozen durian combined with use of the proposed flavor-keeping packaging, the expected increase in the income by applying the proposed packaging will be P. 61/kg, or P. 196,000/ha as shown below.

	Per kg	Per 1 ha of farm
Current (fresh durian)	P. 17	P. 51,000
Frozen flesh	P. 78	P. 247,000
Increase in income	P. 61	P. 196,000

Assumptions:

- Yield per ha.= 3tons; unsold rate = 15% of harvest; sales price in season = P. 20/kg
- Price of frozen flesh of durian = P. 110/kg (ex-factory), including the cost of packaging material; excluding the freezing costs

(For detail, see Table 2-3-7)

Table 2-3-7: Expected Economic Effects of Application of the Proposed Technology/Method

Durian (1) (Fresh-Frozen Durian)

Decrease in unsold stock of Durian, and increase in sales price with;

1) Freezing the durian flesh, and

2) Development of flavor keeping package for the frozen flesh

➡ **Effect:** Reduction of the unsold loss of 15% of durian harvested.
Increase in sales price with improved frozen durian packaging.

Practice/ actions	Revenue and costs/expenditure		Per kg			Amount/ha (Assuming 3tons /ha of harvest)	Basis of the revenue/costs/expenditures estimate
			Volume	Unit price	Amount		
Current practice (No packaging) 	Sales (@ local shop in Davao)	Shipment	1	20	20	60,000	Sales price P.20/kg @Local shop in season Assumed unsold stock : 15%
		Loss (unsold loss)	0.15	20	3	9,000	
		Net sales			17	51,000	
	Costs & expenses			(Not applicable)			
		Sub-total (*2)					
	Balance (*1)				17	51,000	
Proposed practice Stylo foam container with hand-carrying carton cover carrying frozen durian packaged in flavor keeping film package	Sales (Ex-factory)	Shipment	0.75	110	83	247,500	1 kg of fresh durian = 0.4 kg of flesh = 0.75 pack of frozen flesh (0.53 kg/pack)
		Loss	0.0	110	0	0	
		Net sales			83	247,500	
	Costs & expenses	Flavor keeping package	0.75	6	5	193	Packaging material: P. 5-6/pack
		Freezing cost	0	(Not applicable)		0	Not available
		Sub-total (*2)			5	193	
	Balance (*1)				78	247,307	

▼Increase in profit/increase in required investment (Δ*1/Δ*2): (812-546)/(413-310)=2.6

▼Increase in sales amount with keeping the product until off-season = 247% (without taking into account of the costs and expenses to freeze the product, while neglecting the price increase with freezing).

The sales price is also expected to increase with expansion of sales from the local sales shops, to the shops targeting visitors, like that of the airport. Difference in the sales prices among different market is as much as P. 50/pack.

Local shops	P. 125/pack
Shops at the airport	P. 175/pack

There is further possibility of expansion to the shops in big cities such as those in Manila.

2.3.3 Extension of Frozen Storage Capacity of Hand-carrying Box and Transport Container of Frozen Durian Flesh

(1) Hand-carrying box for packaged frozen durian

1) Requirements for the packaging to be developed

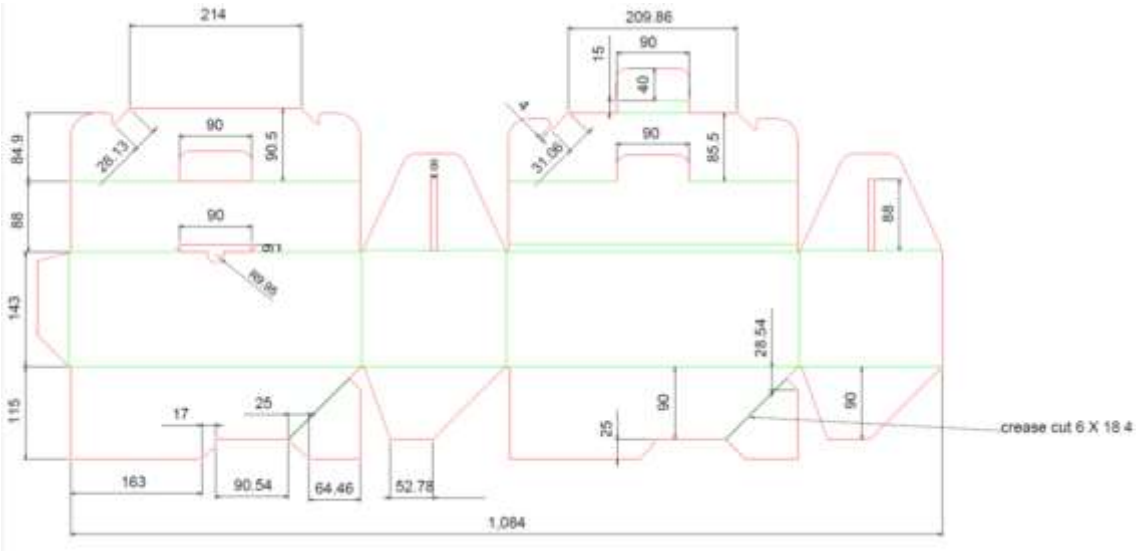
The hand-carrying box to be developed needs to be efficient and have good cold-keeping properties that keep the content frozen up to 24 hours for the convenience of international tourists. Packaging development involves studying the possibility of:

- Using water-proofed corrugated fiberboard, in replace of the EPS box, assuming the better cold-keeping properties and cost-effectiveness; and
- Using cooling agents to prolong the frozen temperature, also assuming the cost-effectiveness.

2) Proposed specifications of the packaging to be developed as a hand-carrying box of frozen durian

a) Hand-carrying box of wax-coated corrugated fiberboard

b) Hand-carrying box of non-coated (regular) corrugated fiberboard

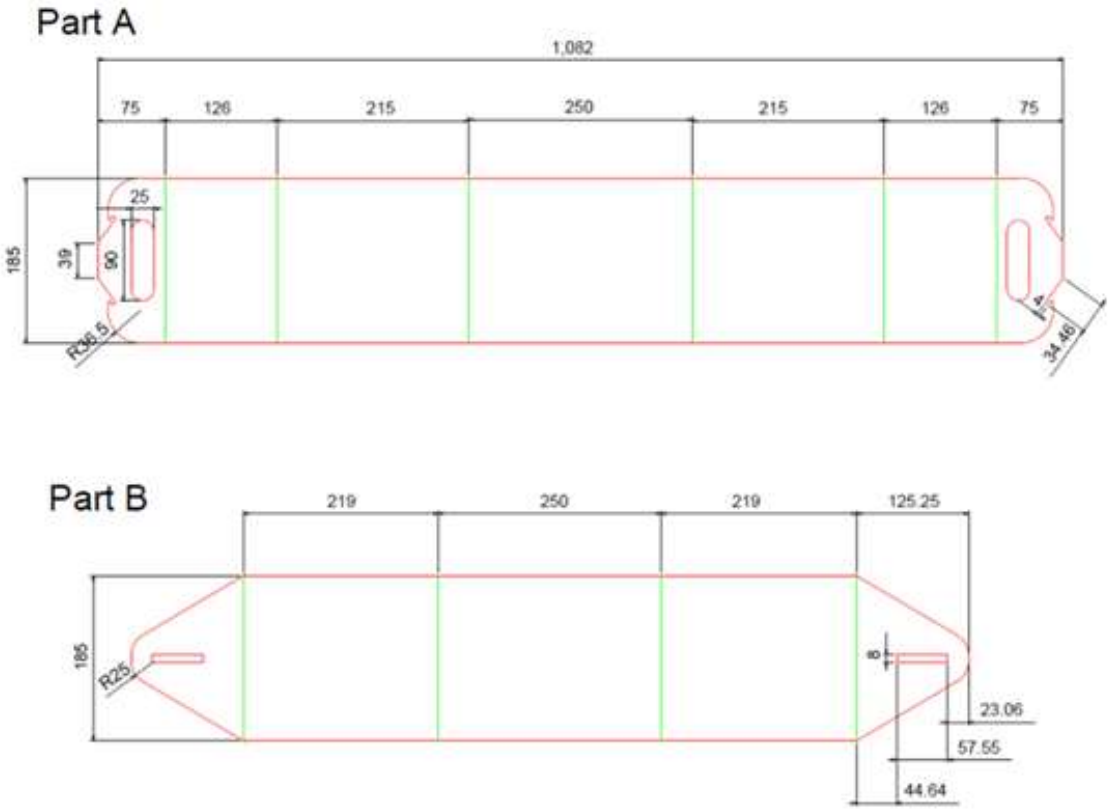


C flute Inside dim: L360 × W176 × H135mm

Note: The box structure is the same whether or not the corrugated fiberboard material is wax-coated.

Figure 2-3-3 Proposed Hand-carrying Box Structure for Packaged Frozen Durian

c) EPS box with corrugated fiberboard handle



C flute corrugated board

Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

Figure 2-3-4 Proposed Handle Structure of Hand-carrying EPS Box for Frozen Durian

3) Verification of effectiveness

The target hours of frozen storage, 10 hours for the corrugated boxes and 24 hours for the EPS box, were met with all the proposed hand-carrying boxes as presented in Table 2-3-8. It will save the packaging cost to select an appropriate hand-carrying box depending on the travel distance, either the corrugated or the EPS box.

The wax-coated corrugated box did not show significant increase in cold-keeping capacity as compared to the non-coated one. Dew condensation inside the box was observed slightly in the cases without cooling agents. From the viewpoint of local availability and cost-effectiveness, however, use of wax-coated corrugated boxes or cooling agents is not necessarily recommended.

Table 2-3-8 Cold-keeping Properties of Proposed Hand-carrying Boxes for Frozen Durian

	Cooling agent	Frozen storage (hours)	⊿Temperature per hour
a) Corrugated box (wax-coated) L360×W176×H135mm Content: 8 frozen durian packages	0	12.5	1.61
	1	13.5	1.46
b) Corrugated box L360×W176×H135mm Content: 8 frozen durian packages	0	13	1.57
	1	18.5	1.41
c) 40x EPS box L230×W230×H175mm Content: 7 frozen durian packages	0	22	0.97
	1	>24	0.71

Note: Tests conducted in January-February 2014. Change of temperature over time was recorded by attaching a sensor inside the box. ⊿*Temperature* is the hourly average from the time when the temperature started to increase.

(2) Transport packaging of packaged frozen durian

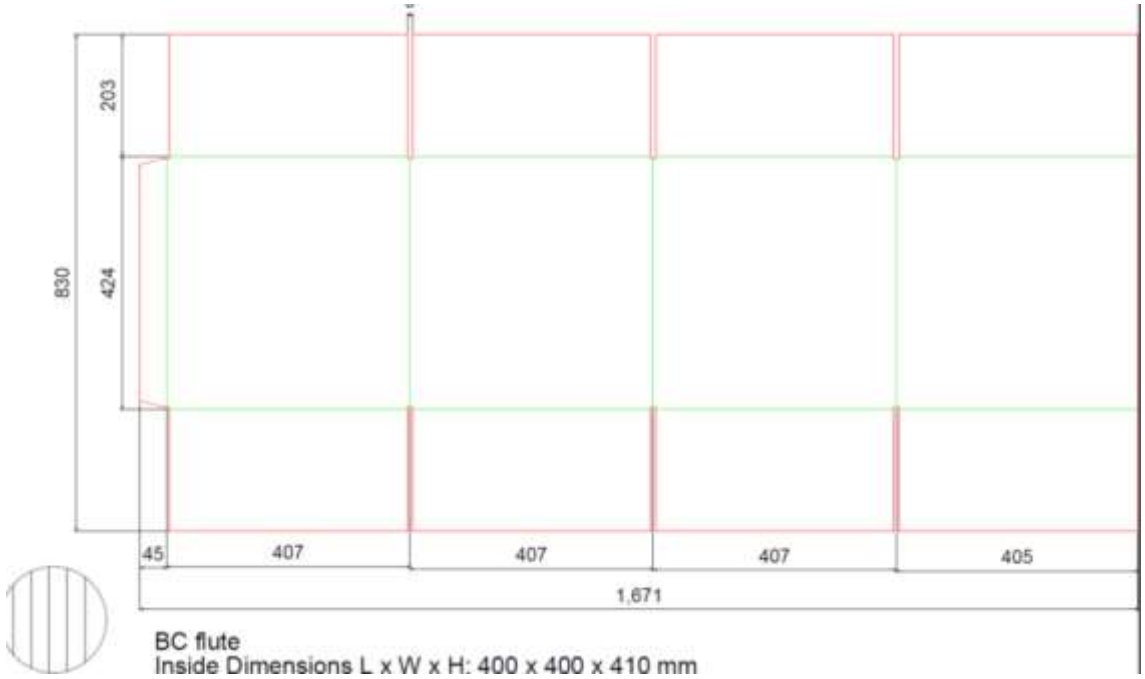
1) Requirements for the packaging to be developed

The transport packaging to be developed needs to have equal or higher cold-keeping capacity in comparison to the EPS box currently used for bulk transportation of packaged frozen durian. That way collapsible corrugated boxes will have chance to replace the EPS box which takes up space even when empty. Accordingly, a corrugated transport box with cold-keeping properties sufficient to keep the product frozen for up to 24 hours is required.

2) Proposed specifications of the packaging for commercial distribution of frozen durian

a) Wax-coated corrugated fiberboard box

b) Non-coated (regular) corrugated fiberboard box



Note: The box structure is the same whether or not the corrugated fiberboard material is wax-coated.
Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

Figure 2-3-5 Proposed Transport Box Structure for Frozen Durian

3) Verification of effectiveness

The proposed packaging generally kept the content frozen up to 24 hours, except the top layer which recorded above-freezing temperatures before reaching the target hours. While the wax-coated corrugated box and the use of cooling agents both extended the frozen-storage hours, it was not effective enough to realize the required cold-keeping capacity.

Nevertheless, the potential of corrugated transport packaging has been demonstrated. Improvements on strengthening heat insulation at the upper part of box will pave the way to actual utilization of the proposed package

Table 2-3-9 Cold-keeping Properties of Proposed Transport Boxes for Frozen Durian

	Cooling agent	Layer	Frozen storage (hours)	⊿Temperature per hour
a) Corrugated box (wax-coated) L400×W400×H410 Content: 50 frozen durian packages	0	Top	11	1.19
		Middle	>24	0.77
		Bottom	>24	0.63
	4	Top	18	1.09
		Middle	>24	0.95
		Bottom	>24	0.99
b) Corrugated box L400×W400×H410 Content: 50 frozen durian packages	0	Top	5.5	1.25
		Middle	>24	0.68
		Bottom	>24	0.68
	4	Top	9.5	1.23
		Middle	>24	0.53
		Bottom	>24	0.63

Note: Tests conducted in February 2014. Change of temperature over time was recorded up to 24 hours by attaching sensors at the top, middle, and bottom layers of the content. ⊿*Temperature* is the hourly average from the time when the temperature started to increase.

2.3.4 Strengthening of Transport Packaging of Fresh Whole Durian

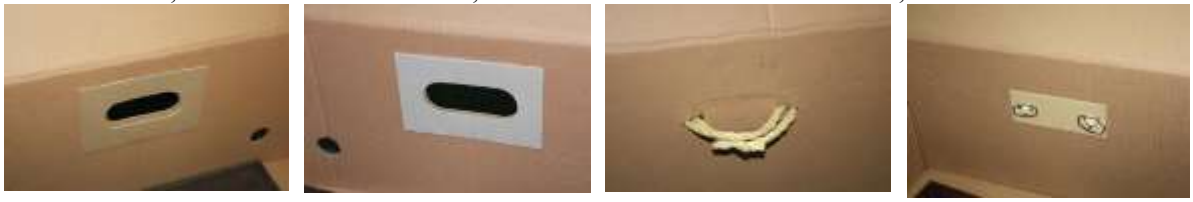
(1) Requirements for the packaging to be developed

Handle strength of the corrugated box needs to be improved so that the package supports handling the load weight of up to 30kg.

(2) Proposed improvements of transport packaging for fresh whole durian

Application of reinforcing boards was proposed as a countermeasure for breakage of hand holes during transportation.

Tube board L150xW100; T:2mm | Chip board L150xW100; T:2mm | Cardboard with cords L135xW50; T:1.5mm



Note: The reinforcing boards are product samples brought from Japan and not supplied in the Philippines as of January 2017.

Figure 2-3-6 Proposed Reinforcing Boards for Hand Holes of Transport Packaging

(3) Verification of effectiveness

Results of the lifting and dragging tests showed that reinforcing boards were effective in strengthening the hand hole of the transport package. The boards are not readily available now in the Philippines, however. It will be a subject for future research to find ways to source the reinforcing board or to develop substitute materials.

Table 2-3-10 Strength of Hand Holes

		Load weight (kg)					
		13	26	39	52	65	78
Proposed packaging With hand hole reinforcing boards (Tube board)	Lifting	OK	OK	OK	OK	-	-
	Dragging	OK	OK	OK	OK	NG	-
(Chip board)	Lifting	OK	OK	OK	OK	-	-
	Dragging	OK	OK	OK	OK	NG	-
(Cardboard with cords)	Lifting	OK	OK	OK	OK	-	-
	Dragging	OK	OK	OK	OK	OK	NG
Control Without reinforcing boards	Lifting	OK	OK	NG	-	-	-
	Dragging	OK	NG	-	-	-	-

Note: Tests conducted in January 2014. The maximum load weight was set at 52 kg (stacking four boxes) for the lifting tests to avoid the risk of dropping the box on the foot when the hand hole breaks.

(4) Assessment of viability of the proposed technology and method

By improvement of transport packaging with;

1 Prevention of rotation and movement of the fresh durian in its transport container (box) during transportation and handling, and

2 Reinforcement of handling holes of transport box of fresh durian,

the damaged durian for export caused by damage to transportation packages is expected to be solved. With this improvement, the reduction of current loss of 15-20% of the shipment is estimated to be P. 207/box (or P. 52/pcs).

For detail, see Table 2-3-11.

Table 2-3-11: Expected Economic Effects of Application of the Proposed Technology/Method

Durian (2) (Fresh Durian)

Improvement of transport package of fresh durian:

1) Prevention of rotation and movement of durian in transport container (box) during transportation and handling

2) Reinforcement of handling holes of transport box

➡ **Effect:** Reduction of 15-20% loss of durian for distance markets (incl. export), caused by damages on transport package

Practice/ actions	Revenue and costs/expenditure						Basis of the revenue/costs/expenditures estimate
			Per box			Amount/pcs (Pesos/pcs)	
			Volume	Unit price	Amount		
Current practice Corrugated box (No partition inside the box; no reinforcement board to handling holes)	Sales (@ Manila)	Shipment	13	160	2,080	520.0	Fresh durian 13kg/box (4pcs/box) Sales price P.25-60/kg @ Davao P.160-170/kg @ Manila Loss during post-harvest & transportation: 15-20%
		Loss	2.0	160	312	78.0	
		Net sales			1,768	442.0	
	Costs & expenses	Box (*2)	1	20	20	5.0	Unit price of the corrugated board P. 20-50/box @ Benguet (subject to change depending on size and thickness)
		Air cargo from DVO to MNL	13	20	260	65.0	P. 20/kg
		Sub-total			280	70.0	
	Balance (*1)				1,488	372.0	
Proposed practice Corrugated box (Placement of partition inside the box; attachment of reinforcement board to handling holes)	Sales (@ Manila)	Shipment	13	160	2,080	520.0	
		Loss	0.0	160	0	0.0	
		Net sales			2,080	520.0	
	Costs & expenses	Box (*2)	1	50	50	12.5	Better quality box
		Partition & reinforcement board (*2)	1	75	75	18.8	(Assumption) Partition P. 40/box Reinforcement board: P. 35/box
		Air cargo from DVO to MNL	13	20	260	65.0	
		Sub-total			385	96.3	
	Balance (*1)				1,695	423.8	

▼Increase in profit/increase in required investment (Δ*1/Δ*2): (1,695-1,488)/(135-20)=1.8

2.3.5 Development of Promotional Consumer Packages to Penetrate into Untapped Markets

(1) Requirements for the packaging to be developed

The packaging graphic design to be developed should promote the positive brand image of Philippine durian in the international market. For this purpose, the package design needs to:

1. Reflect the brand concept that represents the unique value of the Philippines as durian-producing area and thus distinguishes Philippine durian from other durian in general;
2. Establish the brand identity by ensuring the uniform tone and style of visual appearance across different types of packaging; and
3. Provide sufficient information about the fruit, such as nutritional benefits, serving suggestions, and local cultural implications, to encourage adoption by the target consumers who are not always familiar with the fruit.

(2) Proposed packaging graphic design for durian from Davao

1) Graphic design for proposed individual and collective packages

a) Flavor-keeping flexible packaging of frozen durian

Frozen packaged foods in general often fail to provide a good vision of the content. The product name only is printed on the packaging film in many cases, given that the logo will be easily deformed if printed on the surface of flexible package.

A package with header label was the target style from the start, since applying a sticker label would not eliminate the possibility of deformation.

See Table 2-3-5 for the film specifications.

Fancy hand-carrying boxes with a handle are developed to promote purchases as souvenirs and gifts. The graphic design is applied on the box by four-color offset printing. There are two types of hand-carrying box proposed: one that contains individual packages immediately and another that covers an EPS box container and provides a handle. The graphic combined visual images selected from the perspective of regional branding with intent to present the produce as a local specialty.

b) Corrugated fiberboard hand-carrying box for frozen durian

See Figure 2-3-3 for the structural design.

c) EPS box with a handle for hand-carrying frozen durian

See Figure 2-3-4 for the structural design. The two-piece structure is selected for its material-yield efficiency.

2) Promotional materials

For the purpose of promoting better appreciation of the product value, regional brand promotional materials are trial-developed to deliver additional information and enrich the consumer's experience of buying durian. The climate for growing quality durians, frozen durian processing, nutritional values, serving suggestions, and other practical knowledge are incorporated to promote recognition and appreciation of durian.

a) Product poster for blast-frozen durian in the flavor-keeping package (A2-size)

b) Brand brochure (A4-size, three-fold)

(inside)

(outside)

(3) Verification of effectiveness

The proposed packaging was presented to potential buyers and consumers at the following international and domestic exhibitions.

- International Food and Beverage Exhibition (FOODEX JAPAN) in Tokyo, Japan (March 2014)
- National Science and Technology Week in Manila (July 2014)
- BIMP-EAGA[1] and IMT-GT[2] Trade Fair in Davao (October 2014)
- Hong Kong Food Expo (August 2015)
- International Flower Expo Tokyo (IFEX) (October 2015)
- Asian Food Show in Osaka, Japan (October 2015)

The flavor-keeping frozen durian packaging was highly appreciated especially by Japanese and Chinese visitors at the international exhibitions who were interested in importing the blast-frozen durian product. The exhibition in Davao received many local durian growers and processors, and they appraised the proposed packaging design as distinct, representing local characteristics, and appealing. The exhibition also drew growers' attention to the blast-freezing technology and promoted their interest in adopting it.

[1] Brunei Darussalam, Indonesia, Malaysia, Philippines - East ASEAN Growth Area
[2] Indonesia, Malaysia, Thailand - Growth Triangle

2.3.6 Remaining Issues and Recommendations

(1) Further improvement of user-friendliness of the flavor-keeping frozen durian package

While the proposed and verified double-packaging technology is complete with the primary function to confine the durian aroma, room for betterment remains. The following are examples of improvements that can be made for greater usability.

- Provide a notch for easy tear-opening
- Provide a re-closable zipper to the outer pouch
- Provide an easy-opening tape or string to the inner pouch

(2) Marketing promotion to accelerate adoption and dissemination of the developed flavor-keeping packaging technology

It is the market force that best promotes introduction of new technologies; durian growers and processors will take a step forward to adopt the developed flavor-keeping packaging technology when they are assured that the consumer will have a stronger need for the new product than for the conventional frozen durian. The following measures may be taken in cooperation with early adopters so that the new product will gain positive recognition and establish an advantaged position in the market.

- Adjust the packaging to reflect consumer preferences on:
  - Unit volume per package
  - Variety (specific varieties of durian to be promoted for particular market segments, occasions, etc.)
- Utilize promotional tools and materials such as brochure and point-of-purchase displays that provides information of nutritional benefits, serving suggestions, etc.
- Run a sales campaign and sampling activity

2.4 Mangosteen

2.4.1 Current Post-harvest and Distribution Practice and Needs of Improvement

(1) Production

The statistical data of BSA on production of mangosteen, seem to be erratic, fluctuating significantly year by year. The data in 2005 and 2010 indicates more than 5,000 tons are produced in total Philippines, whereas the data in recent 3 years of 2013 through 2015 indicate the annual production is 3,000 tons level. Davao is estimated to have accounted for 9-15% of the national production, according to the data.

The major production area of mangosteen in the Philippines is Sulu province, accounting for 70-83% of total production in the Philippines, again, according to the statistics.

(Unit: ton)

	2005	2010	2013	2014	2015
Philippine total	5,151	5,552	3,303	2,685	3,400
Davao Region	477	700	302	447	461

Harvest season of mangosteen is basically once a year in July through September in Davao. Department of Agriculture is now promoting to program the second harvest season in February through March adjusting flowering with controlling watering timing.

In the case of Sulu Island, mangosteen is harvested once every two years.

The mangosteen of Davao, is mostly sold fresh in the local fruits shops/markets, while one freezing plant has started their operation of mangosteen blast freezing. Other demand for mangosteen is that for raw material of herb tea and medicine, using the pericarp.

(2) Harvest, post-harvest and distribution practice

1) Harvest

The stages of maturation of mangosteen can be classified into 6 stages. The color of mangosteen changes stage by stage from (1) green, (2) light yellowish green, (3) pink, (4) reddish purple, (5) dark purple and (6) blackish brown. If it is harvested at the stage of light yellowish green (or Stage 2), the color changes to pink in 2 days. Most

of mangosteen is sold at the stage of (4) or (5). In this case, the shelf-life of them is 4-5 days. However, if it is harvested at purple stage, the shelf-life will be 3 days at the longest.

2) Post-harvest and distribution

The mangosteen harvested is shipped immediately without storing at the production site.

For distribution, used-corrugated box for transportation of banana is reused. According to the growers, there have been no significant damages during transportation with this method of transportation packaging, if the corrugated box is filled to almost full level. The mangosteen is transported by vehicles of growers to the local shops/markets (Bankerohan Market, Magsaysay Market, etc.).

The mangosteen is sold at the shops/markets per kilo, displayed hanging at the shops bound in a bunch by plastic string.

Following shows change in prices of mangosteen by month:

(Unit: Peso/kg)

Year / Month	2012	2013	2014	2015
Jan.	..	14.96	..	..
Feb.	24.76	32.26	..	..
Mar.	20.85	21.46	19.72	..
Aug.	36.35	49.96	17.51	31.21
Sep.	39.59	49.94	19.09	22.88
Oct.	44.64	21.1	21.32	39.22
Nov.	26.34	21.76	22.58	..
Dec.	24.09	23.56	23.65	..
Annual average	30.95	29.37	20.65	31.1

Source: BAS (Bureau of Agricultural Statistics)

Although the fresh mangosteen is currently marketed locally, and no particular transportation or consumer packaging is used for the mangosteen in Davao, in the case of Japanese markets, where the mangosteen is regarded as one of the high-value fruit, following types of packaging are used:


生マンゴスチン
約1.8kg


CARNAFOODS
果実の女王
マンゴスチン（冷凍）


1箱20個入り
使いやすい個別包装
贈答用にもおすすめです！

3) Marketability and eating quality

Edible aril of mangosteen is white (snow white) and juicy, sweet, and slightly-acid, with a pleasant flavor.

Physiological disorder induced by pre-harvest and postharvest factors is considered to have a major impact on the appearance and eating quality.

Translucent aril is a result of the major physiological disorder that is developed in the field before harvest. It is presumed to be caused by water penetrating the pericarp into aril, and observed at pluvial seasons.

Impact of mechanical injury on post-harvest quality can be summarized as pericarp cracking, surface scarring, pericarp hardening, aril translucency, gamboge and decay. The color of the calyx is also considered to represent the extent of freshness of the fruit, changing from green to yellowish over time.

Elasticity of pericarp is considered another factor representing freshness of the fruit.

2.4.2 Initial Trials to Define the Issues and Needs of Improvement in the Post-Harvest and Distribution Process of Mangosteen

Some initial trials were conducted to confirm the generally known facts about the quality deterioration of mangosteen, as described in 2.4.1.

(1) Trial to define the end of marketability of mangosteen

Although it is generally known fact that the change in color and hardness of the rind represent change in quality of mangosteen, according to a test conducted to define the end of marketability of mangosteen from appearance, the test did not necessarily support the fact. Rather, the test results showed difficulty in defining the quality deterioration from appearance of the fruits without peeling.

The test was conducted as follows:

1. Procure good quality mangosteen from a supermarket, and pack 2 pcs each in an 20μm OPP pouch with 4 holes.
2. Store all the pouches under the ambient temperature of 30℃.
3. Transfer 1 pouch of them every day to 13℃ refrigerator.
4. On the 7th day, make sensory tests under the ambient temperature.

(2) Trial on possibility of creating MA condition for mangosteen

The trial was conducted to verify that film package will create MA condition for mangosteen, as verified for broccoli, cauliflower and mango.

According to the trials, although the proposed film package (OPP film package with pinholes) showed possibility of MA condition, the oxygen concentration in the pouch still remained as high as 15%. Based on the data on the oxygen concentration in the pouches of different number of pinholes, decrease in number of holes on OPP from current 8-16 holes to 3-6 holes is expected to create the MA conditions for mangosteen.

Besides creation of the MA condition, the film packaging showed good effects against transpiration. However, the individual film packaging showed another difficulty of generation of dew condensation under the ambient temperature.

(3) Trial to confirm quick quality deterioration when it is taken out after being kept in refrigerator for a long time

It is a known fact that mangosteen, which are kept in a refrigerator, can maintain its freshness, but the quality will be damaged in short time (1 day) once it is brought out of the refrigerator.

According to the trail result, storage of mangosteen at low temperature of 13℃ showed good results in terms of freshness preservation. However, once it is taken out from the refrigerator, mold growth came observed on the 2nd day after being taken out from refrigerator.

(4) Trial to maintain the eating quality of mangosteen with freezing

Frozen mangosteen is a product already common in the markets. It is already verified that the freshness can be preserved for long-time with freezing. The current trials conducted to define the effectiveness of 1) pre-treatment by solution containing calcium chloride and citric acid, and 2) packaging for light blocking under the frozen condition.

The trial was conducted as follows:

Preparation of the samples:

1) Harvest: Mangosteen of Stage 4 or 5
2) Open the pericarp and take out the small arils of no seed (Arils with seeds are expected to be used for other purpose)
3) Dip in a solution containing 0.25% calcium chloride and 0.50% citric acid for one minute
4) Blast frozen and put in pouches, and heat sealed
5) Pack the pouches in a Styrofoam box for transportation
6) Store in a freezer (-18℃)

Type of the pouches used:

1) Plastic pouch currently used for packaging of frozen mangosteen arils
2) Aluminum foil laminated pouch (for protection from light)

According to the observation results of the trials, however, the color of pre-treated mangosteen is not necessarily better than that without pre-treatment.

(5) Drop test to observe the change in hardness with mechanical shock

According to the test result, although it is generally known fact that the hardness of rind increases by the external mechanical shock, the test did not necessarily support the fact. The extent of mechanical shock with the drop test did not necessarily coincide with the significant change in the extent of hardness of the rind. It is particularly true in the case where the dropping height is 1.5m or lower, the maximum height likely to be applicable in the actual handling process.

The test was conducted to confirm the change in hardness of the rind up to 24 hours after dropping, as follows:

Hours after dropping	Dropping height		
	1.5m	2.0m	3.0m
2 hours	4 pcs	4 pcs	4 pcs
4 hours	4 pcs	4 pcs	4 pcs
8 hours	4 pcs	4 pcs	4 pcs
24 hours	4 pcs	4 pcs	4 pcs

2.4.3 Proposed Further Trials for Improvement of Post-Harvest Practice and Packaging Development

(1) For freshness preservation

1) Use of perforated OPP pouch for individual package (assuming to store and distribute at ambient temperature)

Improvement of short shelf life is considered as one of the most important issues for mangosteen. The shelf-life of mangosteen sold at the stage of reddish purple and dark purple, is 4-5 days, whereas it will be 3 days at the longest, if it is harvested at purple stage,

In order to develop the packaging effective for MA, further trial is necessary to define the optimum number of holes on OPP pouch. According to the results of the initial trials, the optimum number of the holes was estimated to be in the range of 3-6.

In this case, however, there might need countermeasures against mold growth as a result of the possible dew condensation in the pouch. Use of anti-fogging film was tried but not found not effective. For inhibition of mold growth, see next paragraph.

2) Against mold growth after keeping in refrigerator

Storage of mangosteen at low temperature of 13℃ showed good results in terms of freshness preservation, if mold growth can be inhibited after taken out from the refrigerator. In this context, further trial should be undertaken to verify the effectiveness of pre-treatment of the mangosteen with orthophenyl phenol, or sodium hypochlorite in advance to storing in refrigerator to inhibit mold growth.

(2) Prevention of change in hardness of rind from mechanical shock

Based on the trial results, influence of the mechanical shock on the fruit was concluded as insignificant if the impact of the shock is within the level of shock in the process of handling and transportation (and not in harvesting practice). In addition, the growers also reported that reuse of corrugated box for banana transportation had caused any serious problem regarding the mechanical damage during transportation, so long as the mangosteen is packed at the level of 80% of volume of capacity of the box.

Thus, packaging development to reduce the external mechanical shock was excluded from the proposed method of improvement.

Part 3: Cut Flowers (Ver. 5.0)

3.1 Overview

3.1.1 Current Practice and Needs for Improved Post-harvest Handling and Packaging Technologies

(1) Particularity of the needs for packaging development and post-harvest process improvement with cut flowers in general

Need for packaging development and post-harvest process improvement varies depending on [1] forms of distribution and [2] scenes of final consumption.

Buyers/Clients have different priorities in their selection of cut flowers depending on whether the business relation is expected to be continuous or not:

1. Transactions without prospects of continuous business relations: **Good appearance** is the major appreciation factor of cut-flowers. It is easily evaluable and can be reflected on the price.
2. Transactions within continuous business relations: **Long shelf life** is another appreciation factor besides the good appearance. However, it cannot be evaluated easily, and reflected on the price only in the case of continuing transactions.

Scenes of final consumption, on the other hand, are largely classified as shown below.

1. Intended for appreciation at a short time period for particular occasions: Weddings, funerals, visits to grave, and other purposes for which the ornamental function of cut flowers dissolve when the event is over
2. Intended for a longer time period of appreciation: decorations at households, hotels and restaurants, as well as gifts on Mother's Day, Valentine's Day, etc.

The price range accepted in the final consumption markets (budget or high-end market) has significant implication to adoption of developed packaging and post-harvest technologies. For example, in the case of **higher-end markets,** the packaging development results can be relatively easily accepted by the actual business, even if the increase in the development costs are high, whereas technically beneficial methods may not be viable for lower-value merchandise.

There is a possibility of packaging development to enable the commodity to shift to higher-end markets.

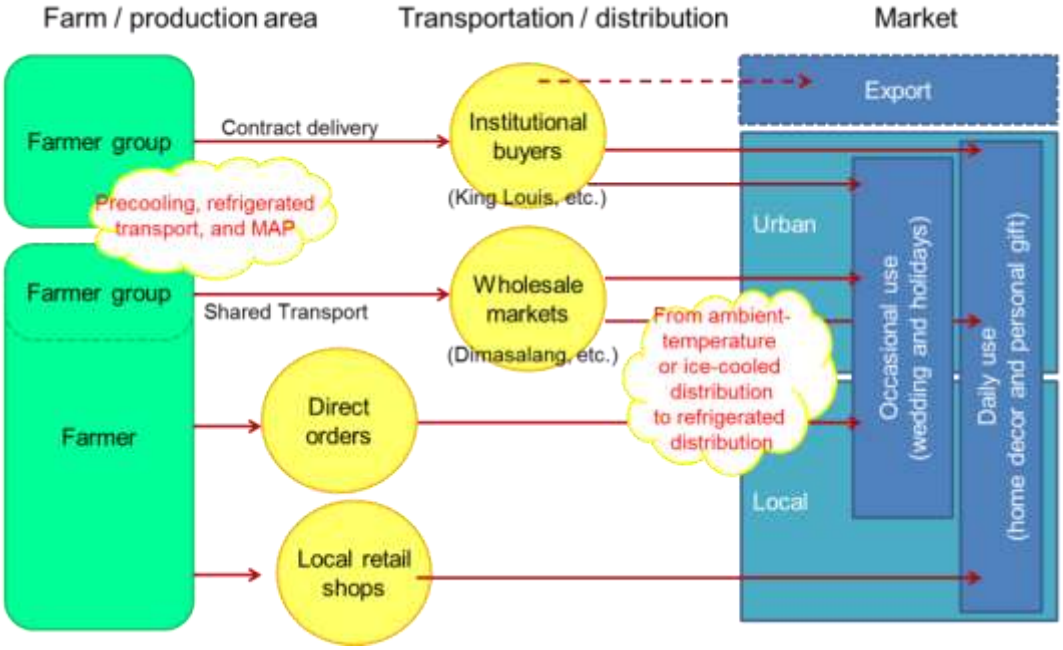
(2) Current practice, issues and needs for improvement of post-harvest practice and packaging development in the Philippines

The following is an illustration of the discussion above in the context of actual practices in Benguet, Philippines.

1) Current distribution of cut flowers

a) Distribution channel

The following shows the current distribution of cut flowers from the production sites to the consumers, in the case of Benguet.



Source: Prepared based on interviews conducted in April 2013 and July 2014 with cut flower growers and traders in Benguet as well as traders at Dangwa Flower Market in Manila

Figure 3-1-1 Distribution of Cut Flowers and Emerging Needs

b) Buyers/customers

Distribution channels are largely fixed according to the grade and variety of flower. Chrysanthemum cut flowers are shipped directly to Manila when the quality clears the required level. Substandard flowers are traded in the Baguio City Market. The price is higher with buyers in Manila as is quality requirements. Regular trade is established between a supplier and a buyer, based on a continued partnership called “suki” in the local language. Roses, on the other hand, are basically traded in Baguio where grower-owned outlets are established. Sometimes roses are shipped to Manila for better prices there. Taking account of the transport costs, however, selling the produce in Baguio tends to be more profitable.

Leftovers that have not taken by the buyer are sold at the market to anyone beyond the "suki" circle.

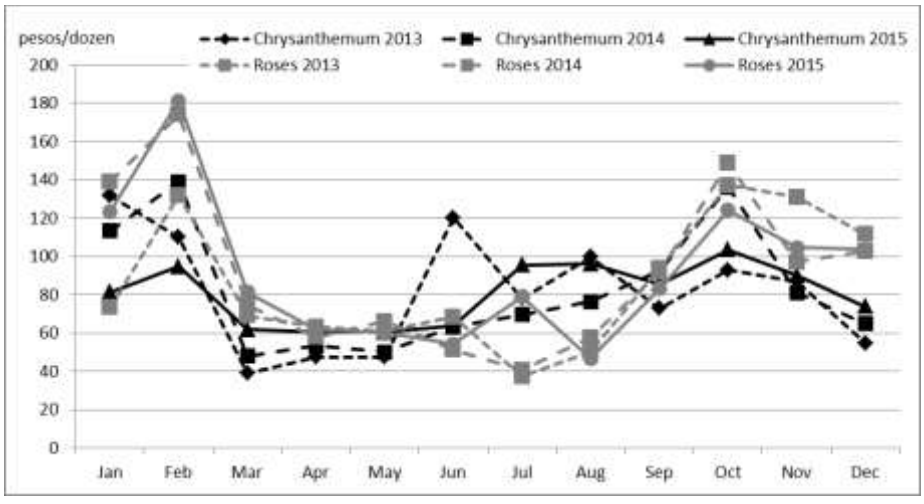
Contract farming is another channel, which provides a fixed price around the year under a yearly contract. Growers are content with the contract price generally.

c) Seasonal demand and price fluctuation

Cut flower consumption hikes at St. Valentine's Day (February 14), Teacher's Day (October 5), All Saints' Day (November 1), Christmas (December 20-28), and wedding seasons. The price sharply increases at these times. Figure 3-1-2 shows how the farmgate price fluctuates in the year for chrysanthemum and roses in Benguet.

Distribution of chrysanthemum starts in October, peaks towards All Saints' Days, and ends in January. Towards All Saints' Day on November 1, the price rises in response to the demands in the urban markets catered via Manila (namely Bicol, Batangus and Visayas) from October 25 to 28, and then in the Manila market from October 29-30. On the first day of November, with the majority of urban residents left for their hometown, the chrysanthemum price drops and remain low for about 10 days. Chrysanthemums are almost unavailable in March even by offering 200 pesos/dozen, a higher price than the normal range of 100-150 pesos. If chrysanthemums were stored until March and then shipped, they would be sold at a high price.

Roses have a sharp price increase around St. Valentine's Day. According to a grower in Benguet, the price hit as high as 350 pesos per dozen in February 2012 as compared to 15 pesos usually.



Source: Philippine Statistics Authority (http://countrystat.psa.gov.ph/). Data retrieved on January 6, 2017.

Figure 3-1-2 Farmgate Prices of Chrysanthemum and Roses in Benguet

d) Grading

Cut flowers are graded according to the size regardless of color, shape, or foliage conditions. The standard-type (single flower) chrysanthemums are classified by flower diameter; the flowers are sorted into four grades from excellent (approximately φ4in.) to large, medium, and petite (approximately φ1in.). The blooming stage is not counted when measuring the flower diameter. Retailers prefer half-bloomed flowers while full-bloomed flowers are in demand for immediate use such as ornamental arrangements for special events. It is worth noting that the flower diameter is not measured one by one but by the volume of flower part of a bunch. A bunch of spray mums may contain more than 12 pieces for the number of flowers on a piece affects the flower volume of the bunch.

Grading of spray mums refers to the length of stem, no matter how large the flower diameter is. The flowers are classified into five grades: class AA (>80cm), long (>70cm), medium (>60cm), short (>50cm) and class B (>45cm). The flowers on 45cm or shorter stems are rejected. Flower growers and traders in Benguet are all aware of the criteria which accord to the national standard. Actually, it is not that the length alone matters, but also required are the firmness of stem that upholds the flower weight when turned sideways from the cut end, as well as the well-balanced shape of the whole piece.

Dealers of import flowers also apply the stem length as grading criteria. The size of flower is not among primary factors. Likewise, color and shape of flower is just need to be normal (without disease, deformation, or chemical residue) and unimportant to grading.

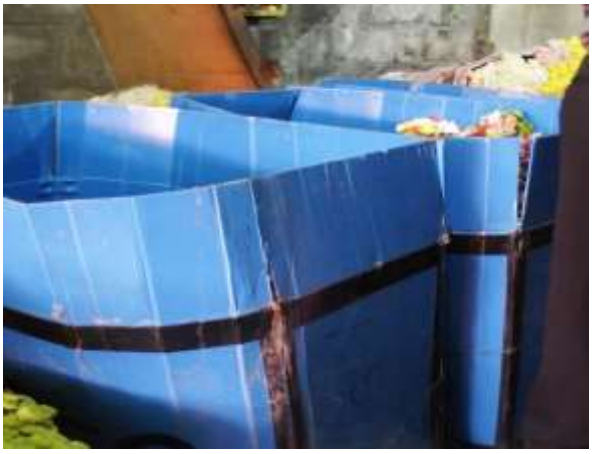
The price is differentiated by grade; for example, when the class AA grade is priced at 100 pesos, the L grade may be 80 pesos, the M grade 60 pesos, the S grade 40 pesos, and the class B grade 20 pesos. One day in July 2014, a dealer at the Benguet City Market was selling spray mums at the prices of 150 pesos for the class AA, 120 pesos for the L, 90 pesos for the M, and 60 pesos for the S grades.

An important finding here is that the length of vase life is not reflected on the price.

Dangwa Flower Market

Imported flowers kept in refrigerated chamber

Imported flowers packaged in nonwoven cloth/film and kept with freshness-keeping agents



Big corrugated plastic boxes used for transportation of chrysanthemum

Big EPS boxes used for transportation of roses with a block of ice as cooling agent

2) Current issues need of focus for improvement of post-harvest practice and packaging development of cut flower in the Philippines

Following are the major issues which have been encountered by the growers and distributors of the cut-flowers in the Philippines:

a) Demand concentration and price fluctuation

Market demand for some cut flowers, including chrysanthemum and rose, concentrates in a few specific days before All Saints' Day and St. Valentine's Day seasons, etc. The commercial value of these cut flowers sharply drops the next day it peaks.

The growers, however, without sophisticated production and shipment control, cannot help bearing losses due to untimely harvesting.

b) Deterioration of quality in the distribution process

Out of desire to minimize the cost of transportation and transport packaging, growers tend to put as many flowers as possible in a transport container. As a result, the flowers are compressed and rubbed to suffer mechanical damages during transportation.

During ambient-temperature transportation in a box without ventilation holes, accumulated heat in the box accelerates respiration of the flower and deterioration of freshness.

c) Inefficiency in transportation of cut-flowers

Most cut flowers are shipped at half- to full-bloomed stages in the current practice. The flower part is much bigger in diameter as compared to the cut-end part of a bundle, which makes transport efficiency low.

3.1.2 Quality Preservation of Cut Flowers

(1) Factors of quality deterioration specific to cut flowers

Cut flowers are alive even after harvested. In this regard, factors affecting the quality of fruits and vegetables also work on cut flowers in principle (refer to 3.1.1).

Table 3-1-1 Factors Affecting Quality of Cut Flowers

Factors affecting quality of cut flowers	Deterioration of quality
Respiration	Loss of sugar, acid, and vitamins
Transpiration	Withering and weight loss
Metabolism	Aging of cellular systems
Growth of microorganisms	Spoilage
External forces during transportation	Mechanical damage

Source: Prepared by the JICA Project Team

The flower is the most active part of a plant physiologically which has the fastest respiration rate. Rapid energy consumption after harvested is an important issue in quality preservation of cut flowers.

In addition, the market value of cut flowers is judged from particular perspectives that are not necessarily applicable to vegetables.

1. Appearance is the priority in quality evaluation, which is easy to measure and reflect on the price.
2. The vase life may be considered but is difficult to measure at the point of transaction in practice. Under repeated transactions, a production site may win the buyer's appreciation of reliability that turns to a higher price. The vase life should refer to the period that the acceptable appearance is maintained.
3. Food safety regulations are not applied to cut flowers as they are not for food.

(2) Freshness preservation technologies

Conditions required for freshness preservation of cut flowers are basically the same as those for fruits and vegetables. Focal points are different (refer to Table 3-1-2).

1. The issue of first priority is to maintain the level of moisture content by keeping water uptake of the flower. Sustained moisture content is a prerequisite for countermeasures to aging caused by ethylene generation or to loss of nutrients caused by respiration. In other words, it is useless to address ethylene and respiration issues unless the moisture content is maintained.
2. The second key to freshness preservation is to slow energy consumption through respiration of the flower. To harvest and transport the flowers at the bud stage is a solution for this purpose, once it is guaranteed that the bud will open after reaching the target market.

Low temperature that suppresses respiration and transpiration is the most fundamental consideration in freshness preservation of cut flowers, as is the case for fruits and vegetables. While few cases of modified atmosphere (MA) packaging are known to be applied on cut flowers practically, several chemicals are proved to be effective for prolonging the vase life of cut flowers, a list of which is provided in Table 3-1-3.

Table 3-1-2 Causes and Preventive Means for Quality Deterioration of Cut Flowers

Major causes of quality deterioration of cut flowers		Quality deterioration	Possible means to prevent quality deterioration	
Respiration	Loss of sugar, acid and vitamins	- Yellowing of leaves	Restrain respiration by lowering product temperature	- Practice pre-cooling and cold storage
			(Restraining respiration by adjusting gas composition is not common for cut flowers)	
Transpiration	Loss of moisture	- Wilting of flower and leaves - Bent flower neck	Restrain transpiration by lowering product temperature	- Practice pre-cooling and cold storage
Reduced water sucking capacity	Poor water uptake		Reactivate water sucking capacity	- Add surface active agents in vase water - Dip in deep water - Use warm or hot water in vase
Decay of stem			Delay progression of decay	- Keep vase water shallow - Cut back spoiled stem end
Vessel clogged with bacteria			Prevent bacterial growth	- Pasteurize vase water - Acidify vase water(<pH 4.0) - Use anti-microbial agents - Wash and clean stem
Vessel clogged with chemicals (polyphenol)			Remove polyphenol in vase water	- Add coagulant in vase water
Vessel clogged with air bubble			Prevent contact with air	- Keep stem in water during transportation
Generation of ethylene	Acceleration of metabolism	- Wilting/drop of petals and bud	Restrain ethylene generation	- Apply ethylene absorber - Apply ethylene suppressor (STS, silver thiosulfate) - Apply ethylene inhibitor
Deficiency of energy for blooming		- Difficulty in blooming especially of young flower and bud	Supplement/replenish energy	- Supply sugars

Source: Prepared by the JICA Project Team

Table 3-1-3 Chemicals Used for Extension of Vase Life of Cut Flowers

Purpose	Target	Symptom	Agents	Chemicals
Accelerate water uptake	Microbial growth	Stem blockage	Germicide / disinfectant	- Sodium hypochlorite - KATHON CG - Silver nitrate - Isothiazolinone - Quinoline group - Quaternary ammonium compound (Physan-20)*
			Acidifier (optimum pH3.5)	- Citric acid - Ferric sulfate
	Polyphenol	Stem blockage	Coagulant	- Aluminum sulfate [$Al_2(SO_4)_3$]
	Interfacial force	Disturbance of water absorption	Surface active agent	- Polyoxyethylene lauryl ether, etc.
Replenish energy	Nutrition	Aging Blooming Flower size and color Leaf yellowing Wilting	Sugar (Osmotic pressure) (Energy)	- Glucose - Fructose - Saccharose - Hydroxyquinoline citrate [HQC] + Saccharose
Prevent over-maturing	Ethylene generation	Leaf yellowing Flower senescence	Ethylene inhibitor	- Silver thiosulfate [STS]

Note: Use of quaternary ammonium compound (Physan-20) is officially required in Holland.
Source: Prepared by the JICA Project Team

The sensitivity to ethylene varies depending on the kind of flowers, as shown in Table 3-1-4. Relevance of controlling ethylene generation will be judged accordingly.

Table 3-1-4 Sensitivity to Ethylene

Level of sensitivity	Kind of flower		
High	Carnation Orchids	Sweet pea	Delphinium
Relatively high	Snapdragons Texas bluebell	Rose Alstroemeria	Southern star
Relatively low	Gilly flower	Thunbeng lily	Daffodil
Low	Chrysanthemum Gerbera Tulips	Gladiolus Dahlia Easter lily	Sunflower Freesia

Source: Kazuo Ichimura, "Kaki no Hinshitsu-hoji to Sendo-hosho [Quality Preservation and Freshness Guarantee of Flowers and Ornamental Plants]." *Monthly Journal of Agriculture and Extension,* Vol. 49, No. 25. 2007.

There are two types of cut flower preservatives in terms of treatment timing in the distribution process: pre-treatment to be applied by the grower for a short time before shipment and post-treatment to be applied by the retail shops or the consumer for a consecutive time period.

Cut-flower growers and distributors practice some of the freshness-keeping measures, although to a limited extent, as summarized below.

1. Reactivation of water absorption in the production area:
   The growers let harvested flowers absorb water for one to four hours. Well water, tap water, rain water, and pumped-up river water is used. Some dealers request growers not to water the harvested flower so that freshness of the flower is easily judged; the dealer practices a method of reactivating water absorption after accepting the transported flowers.
2. Freshness-keeping agents:
   Freshness-keeping agents are not added to the water in which the flowers are soaked after harvested. When the prices are high, lemon/lime juice and sodium hypochlorite may be added to the water. Retail stores do not use freshness-keeping agents either, at least for domestic products.

(3) Transport methods for cut flowers

Truck transportation of cut flowers in general takes either dry or wet conditions.

1. Dry condition: the flower is not supplied with water or freshness-keeping solution during transportation
2. Wet condition: the flower is supplied with water or freshness-keeping solution during transportation

Wet-conditioned transportation includes [1] wet-conditioned boxed transportation in which the flower is supplied with water in a flexible vial attached to the stem end, and [2] bucketed transportation which carries the flower put in a bucket of water (in some cases the bucket of flowers is placed in a side-opening corrugated box). Both types of wet-conditioned transportation prevent weight loss of cut flowers during transportation.

In the Philippines, pre-cooling is hardly practicable even though it is a prerequisite to low-temperature distribution, and infrastructures are yet to be developed for a cold chain throughout the distribution processes. Given that most cut flowers stand for dry conditions up to a few days, the discussion hereunder assumes dry-conditioned transportation.

Table 3-1-5 Methods of Cut Flower Transportation

Transport method		Advantages	Disadvantages
Dry-conditioned		• Suppress growth/aging of the flower during transportation	• Hinder resumption of water absorption for roses and other flowers susceptible to air intrusion into the vessel.
Wet-conditioned	Boxed	• Easy to preserve freshness • Able to add chemical agents in vase water during transportation for pre-treatment which is otherwise applied before shipment • As efficient as dry-conditioned transportation	• Become stuffy inside the container under ambient temperatures • Accelerate growth of the flower under ambient temperatures with well-maintained moisture condition, resulting in shifting of flower necks and progression of blooming.
	Bucketed	• Easy to preserve freshness • Able to add chemical agents in vase water during transportation for pre-treatment which is otherwise applied before shipment	• Accelerate blooming under ambient temperatures • Poor efficiency of transportation • Need a process to return empty buckets

Source: Prepared by the JICA Project Team based on Japan Flower Promotion Center Foundation (Ed.), "Kiri-bana no Sendo-hoji Manuaru [Cut-flower Freshness Preservation Manual]," 1997.

3.1.3 Proposed Improvement of Post-harvest Practice and Packaging Development for Cut Flower

Table 3-1-6 presents freshness preservation measures and their expected effects.

Table 3-1-6 Freshness Preservation Practices for Cut Flowers

Practice	Purpose	Remarks
1) Low-temperature storage and distribution	- Suppress respiration - Prevent ethylene generation and lower ethylene sensitivity - Suppress transpiration - Prevent microbial growth - Decelerate blooming	Prevent sugar consumption
2) Harvesting and distribution at bud stage	- Suppress respiration	The bud has a lower respiration rate than the flower. (The harvested bud must be guaranteed to bloom later)
3) Use of freshness-preserving agents • Supply of sugars	- Supply carbohydrates - Promote water sucking - Prevent ethylene generation and lower ethylene sensitivity - Enhance the color of flower - Suppress chlorophyll degradation - Promote blooming	As a basis for respiration As an osmotic agent
• Prevent obstruction of water absorption	- Maintain the water absorbing capacity	Water absorption is important for maintaining the moisture content. The transpiration rate has greater influence on water absorption than the water sucking capacity. When transpiration is suppressed, less water is to be sucked.

Source: Prepared by the JICA Project Team

Based on analysis of the issues related to post-harvest practice, distribution and transportation of cut flowers, following are recommended in the field of post-harvest practice and packaging for improvement:

(1) Use of chemical agents to preserve freshness and quality

Although distribution and storage at low temperature is the best way for preserving freshness of cut flowers through lowering the respiration and transpiration rates, use of freshness preserving agents is recommended for controlling the shipment timing to meet

the demand season, considering the fact that the pre-cooling facility and reliable cold chain system is not available in the Philippines.

A versatile formula of freshness-keeping chemical solution is proposed as shown in Table 3-1-7. The formula is designed to satisfy basic functions expected from freshness preservatives by using only the chemicals readily available in the Philippines. In practical application, it is recommended to adjust the composition according to the physiological properties of different flower varieties.

Table 3-1-7 Proposed Formula of Freshness-keeping Solution for Cut Flowers

Chemical agent	Concentration	Function
Glucose	1-3%	Sugar to replenish energy and ensure blooming
Aluminum sulfate [$Al_2(SO_4)_3$]	100-200ppm	Coagulant to purify the vase water (remove polyphenols) and prevent vessel clogging
Sodium hypochlorite	100ppm	Disinfectant to inhibit bacterial growth and prevent vessel clogging
Citric acid	100ppm	Acidifier as an axillary agent to enhance the function of sodium hypochlorite

Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

(2) Shipment at bud-stage for distribution efficiency and longer vase life

If cut flowers are stored or transported at the bud stage, the volume per piece of flower will be reduced significantly. Concurrently, quality deterioration from respiration activity will be slowed for the bud has a lower respiration rate than the flower does. In this case, however, there is a need to ensure that the bud will bloom in full, in addition to a need to develop transport packaging to protect the bud from being damaged in the distribution process. Use of chemical agents is recommended again, this time as the method to ensure blooming.

(3) Development of transport package to prevent damage and quality deterioration in the transportation process

There is a need to develop a packaging which is effective for prevention of overstuffing and for prevention of damages during transportation caused by friction.

3.2 Chrysanthemum: Verification of Effectiveness of the Proposed Improvement of Post-harvest Practice and Packaging Development

(1) Feature of cut chrysanthemum

Cut chrysanthemum, as with cut flowers in general, has a seasonal demand. The demand for chrysanthemum peaks just before All Saints' Day on November 1. Consumed for gift and ornamental purposes, chrysanthemum is appreciated for its visual appearance as the key factor of commercial value.

Physiologically, chrysanthemum cut flowers have relatively long vase life, thanks to a good water absorbing capacity and low sensitivity to ethylene. It is known that constant supply of sugars enlarges the flower size.

(2) Current post-harvest and distribution practices

Table 3-2-1 summarizes the post-harvest and distribution practices currently seen in Benguet.

Cut chrysanthemum is transported at ambient temperatures from Benguet to Manila under the dry condition without supply of any freshness-preserving agents.

The most prevalent transport packaging is to use a returnable corrugated plastic box sized W100cm × H60cm × L45cm, which contains 45-50 dozens of class-AA grade (stem length >80cm) mums laid flat and layered with the flower top and the stem bottom directions alternated by layer. The box is durable for 8-10 times of use and costs 300 pesos/piece exclusive of the shipping charge of 10 pesos/piece. Corrugated fiberboard boxes of about the same size are also used as a returnable transport container which costs 60 pesos/piece. Each bundle of flowers is wrapped with newspaper, as plastic wrapping film is not affordable to the growers. Both types of packaging do not have a ventilation hole and the temperature and humidity inside the container are easily elevated by respiration and transpiration of the flower.

Transport fee is 120 pesos/box outward and 20 pesos/box homeward for both types of containers.

Mechanical damages observed at arrival in Manila are mostly crumpled flowers and broken stems that amount for approximately one dozen in every 40 dozens. Damaged flowers, except severely affected ones, are sold at a discount up to 50% or gave away free with any purchase. They are still needed for the purpose of ornamental arrangements at funerals and other social occasions.

Table 3-2-1 Current Post-harvest and Distribution Practices of Cut Chrysanthemum

Current post-harvest and distribution practice			Remarks
Harvesting/shipping		Harvest fully-open flowers	Buyer's requirement
		Soak in water for 1–4 hours	In the season of higher prices, lemon/lime juice and chloride may be added in the water for freshness-keeping effects.
		Sort/grade by flower diameter	Sorting and pricing is made by bundle.
		Shipment follows right after harvesting	
Transport	Dry method at ambient temperature	Returnable corrugated plastic box (most common for chrysanthemum)	To be used for 8 to 10 times
		Returnable corrugated fiberboard box	To keep the transport packaging cost low with minimum efficiency in freight handling
		Returnable stylofoam box (also used for roses)	Only for direct transportation from the grower to Manila markets Sprinkled with water in some cases for prevention of wilting (no use of ice)
Storage/sales		Add Zonrox (chloride) to the water	To prevent odor

Source: Prepared based on the results from field survey conducted in July 2014 in Benguet and in May 2014 in Dangwa Flower Market in Manila

Spray mums in the ready-to-harvest blooming stage

Mums are harvested at the half- to full-bloom stages.

Shelf life is 7-10 days:
- Soaked in pure water or with chloride
- Under ambient temperature

Chloride is the only agent mixed in the water.


Returnable corrugated plastic box (310 pesos/piece, durable for 8-10 times of use)
W 100 cm x H 60 cm x L 45 cm Shipping cost: 140 pesos/box


Returnable corrugated fiberboard box (60 pesos/piece) Shipping cost: 140 pesos/box

(3) Effectiveness of chemical solutions for extending vase life of chrysanthemum

1) Proposed formula of freshness-keeping solution

The formula particularly suitable for cut chrysanthemum has been determined as presented in Table 3-2-2, based on results from preliminary experiments.

Table 3-2-2 Proposed Formula of Freshness-keeping Solution for Cut Chrysanthemum

Chemical agent	Concentration	Function
Glucose	3%	Sugar to replenish energy and ensure blooming
Aluminum sulfate [$Al_2(SO_4)_3$]	100ppm	Coagulant to purify vase water (remove polyphenols) and prevent vessel clogging
Sodium hypochlorite	100ppm	Disinfectant to inhibit bacterial growth and prevent vessel clogging

Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

The preliminary experiments revealed that citric acid had an adverse effect on quality preservation that the leaves withered and dried before the flower ended its appreciated life. The solution without citric acid had the acidity below pH5, or the threshold for proper function of sodium hypochlorite, and thus the proposed chrysanthemum-specific formula excluded citric acid from the composition.

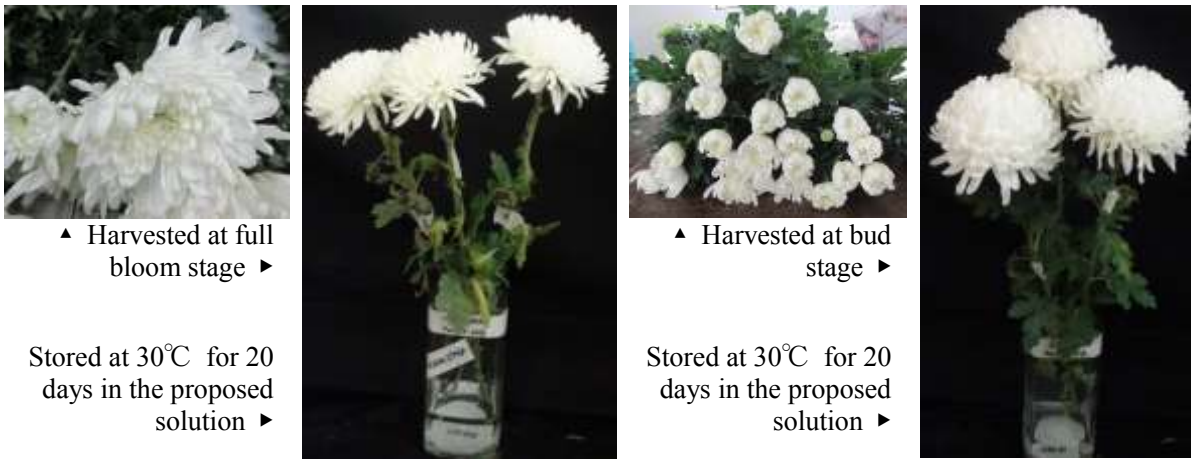
2) Verification of effectiveness

The verification tests confirmed effectiveness of the proposed solution for extending the vase life of cut chrysanthemum. The proposed solution extended the vase life of cut chrysanthemum by 14 days at an ambient temperature (30℃) regardless of whether the flowers were harvested at the full-bloom or the bud stage. Effect of glucose was also evident with growth of the flower diameter. The flower diameter, with the proposed solution, increased threefold to reach the maximum of 110mm on the 17th day and then gradually decreased. In comparison, the water-only case enlarged the flower up to barely 76mm at the end of the vase life.

Table 3-2-3 Vase Life and Flower Size of Cut Chrysanthemum at 30℃

Vase water	Vase life (days)		Growth of flower diameter (harvested at bud stage)
	Harvested at full bloom stage	Harvested at bud stage	
Proposed formula (glucose 3% aluminum sulfate 100ppm sodium hypochlorite 100ppm)	20	23	326% (max. 110mm)
Control (water only)	6	9	217% (max. 76mm)
Variation of proposed formula (glucose reduced to 1%)	17	17	363% (max. 100mm)
(glucose reduced to 2%)	20	20	282% (max. 100mm)

Note: Tests conducted in March 2015. Samples were soaked in the solution from right after harvesting throughout the vase life.



▲ Harvested at full bloom stage ▶

Stored at 30℃ for 20 days in the proposed solution ▶

▲ Harvested at bud stage ▶

Stored at 30℃ for 20 days in the proposed solution ▶

Note: From the same verification tests as Table3-2-3.

Figure 3-2-1 Appearance of Verification Test Samples at Harvest and after Storage

(4) Effectiveness of use of corrugated box for transportation for reduction of damages during transportation

1) Proposed transport packaging

Figure 3-2-2 provides the drawing of proposed transport packaging for cut chrysanthemum. This corrugated fiberboard box will contain 40 dozens of bud-stage chrysanthemums. Each bundle of a dozen flowers is to be placed horizontally in alternating layers inside the box.

BC flute Inside dimensions: W 810 × L 450 × H 300mm

Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

Figure 3-2-2 Structural Design of Proposed Transport Packaging for Chrysanthemum

The proposed packaging was developed based on findings from preceding trials. First, Trials on spray mums under the DOST-funded project titled "Development of Transport Packaging Technology for Cut-flowers (Rose and Chrysanthemum)" had revealed that [1] reducing the capacity of a transport container did not have a significant effect on preventing mechanical damages during transportation, and [2] changing the placement method from the horizontal to vertical orientation resulted in a

remarkable reduction of damages. Second, preliminary trials using samples sourced from Tagaytay, a chrysanthemum producing area proximate to Manila, confirmed that [3] transporting cut chrysanthemums at the bud stage was quite effective in preventing damages as compared to the half- to full-bloom stage transportation.

Accordingly, the proposed transport packaging selected the placement method and the harvest stage which had higher space-efficiency and planned the optimum capacity for one-man handling. In addition, the sets of inner flaps on top and bottom of the box have disproportionate lengths; the longer inner flaps are provided as protection for the flower part of the bundles.

2) Verification of effectiveness

Results of the field trial showed that transporting at the earlier stage of blooming was more effective for damage reduction than transporting in smaller units was. As presented in Table 3-2-4, the rate of flower pieces damaged during transportation decreased to nearly a third when the timing of harvest was changed from the full-bloom to the bud stage, while the quantity contained in the same box increased thanks to better space efficiency. Therefore, as long as an appropriate freshness-keeping agent is provided to ensure subsequent opening of the flower, bud-stage transportation is strongly recommended.

Table 3-2-4 Damages during Transportation of Cut Chrysanthemum

Transport packaging	Capacity (dozen)	Damage % in pieces	Ratio
Proposed packaging (Bud stage; W 810 × L 450 × H 300mm)	40	21.18%	1.00
Comparison (Bud stage; W 850 × L 507 × H 375mm)	56	34.38%	1.62
(Full bloom stage; W 810 × L 450 × H 300mm)	24	58.68%	2.77
(Full bloom stage; W 850 × L 507 × H 375mm)	35	60%	2.83

Note: Field trial (transportation of the sample chrysanthemums on reefer van from the farm in Benguet to the PTD in Metro Manila) conducted on March 4, 2015, which was the day of harvesting.
Damages counted were crumpled petals, compressed and detached buds, fallen petals and broken stems. The damage % is higher than what is quoted by the growers and dealers since such damages that do not practically affect the value of commodity are included here for fine comparison.

3.3 Rose: Verification of Effectiveness of the Proposed Improvement of Post-harvest Practice and Packaging Development

(1) Feature of cut rose

Rose cut flowers are said to have a short vase life due to their susceptibility to sugar deficiency and bacterial blockage of the vessel. Roses show relatively high sensitivity to ethylene.

(2) Current post-harvest and distribution practices

Table 3-3-1 summarizes the current post-harvest and distribution practices.

Table 3-3-1 Current Post-harvest and Distribution Practices of Cut Roses

Current post-harvest and distribution practice			Remarks
Harvesting/shipping		Harvest half-open flowers	
		Sort/grade by stem length	Sorting and pricing is made by bundle.
		Shipment follows right after harvesting	
Transport	Cooled with ice	Returnable EPS box (most common for roses)	Blocks of ice placed on top of the flowers to lower the temperature Holes on the bottom of container to drain the ice water
	Dry method at ambient temperature	Woven PVC cloth	Used for transfer of harvested roses from the garden to the sorting area
		Reused corrugated box	A few boxes jointed to form one big box
Storage/sales		Add Zonrox (chloride) to the water	To prevent odor

Source: Prepared based on the results from field survey conducted in April 2013 in Benguet and in May 2014 in Dangwa Flower Market in Manila

Post-harvest practices and the vase life of cut roses vary among production sites, target markets, and individual traders. A retailer in Benguet said roses would keep up to four days under ambient temperatures or seven to ten days when cooled on ice. The vase life depends on the cultivar, according to the same retailer, as white roses have shorter vase life of three days. On the other hand, retailers at Dangwa Flower Market in Manila claimed one week at an ambient temperature or eight to nine days on ice. The difference in quality-keeping period seems to stem from the pattern of distribution that higher quality roses are

shipped to urban markets while lower quality ones are consumed locally.

Some dealers at Dangwa Flower Market add Zonrox, commercial bleach, in the water to prevent foul odor. The practice, however, is not shared completely in the market. Use of cold storage is limited to imported flowers. Domestic products are kept at the shopfront which is rarely air-conditioned, with exception of high-value roses that are laid on ice for a longer freshness period.

Returnable EPS boxes are most commonly used for transportation of cut roses from Benguet to Manila. The box contains 40-50 bundles of 24-piece roses. The flowers are covered with ice blocks to maintain a cool temperature throughout the seven to eight hours of transportation. Drainage holes are provided on the bottom panel to release the ice water out of the container. The container itself costs 1,050-1,080 pesos/piece and the shipping fee is 240 pesos/box outward and 20 pesos/box homeward.

Field surveys conducted under the "Development of Transport Packaging Technology for Cut-flowers (Rose and Chrysanthemum)" project found that the loss due to broken neck (the primary reason for rejects) during transportation in an EPS box was below 1% of all transported pieces. The rate increased to 5% for flowers transported in a spliced corrugated box.

Harvested at the half-bloom stage and sorted by the stem length


Returnable EPS box (350 or 1,050-1,080 pesos/piece)
W 1,100 x L 500 x H 600 T 50 mm Gross weight 50kg Shipping cost: 260 pesos/box/round trip




Displayed and sold in Dangwa Flower Market at ambient temperatures

(3) Effectiveness of chemical solutions for extension of vase life of rose

1) Proposed formula of freshness-keeping solution

The formula particularly suitable for cut roses has been determined as presented in Table 3-3-2, based on results from preliminary experiments.

Table 3-3-2 Proposed Formula of Freshness-keeping Solution for Cut Roses

Chemical agent	Concentration	Function
Glucose	2%	Sugar to replenish energy and ensure blooming
Aluminum sulfate [$Al_2(SO_4)_3$]	200ppm	Coagulant to purify vase water (remove polyphenols) and prevent vessel clogging
Sodium hypochlorite	100ppm	Disinfectant to inhibit bacterial growth and prevent vessel clogging

Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

2) Verification of effectiveness

Verification tests showed that the proposed formula was comparable to commercial freshness-keeping solutions in prolonging the freshness period of cut rose; it extended the vase life by two days from that of the water-only case at both ambient (30℃) and controlled (15℃) temperatures. The flower diameter enlarged the most with the proposed solution, resulting from healthy blooming and growing of the flower.

Table 3-3-3 Vase Life and Flower Size of Cut Roses

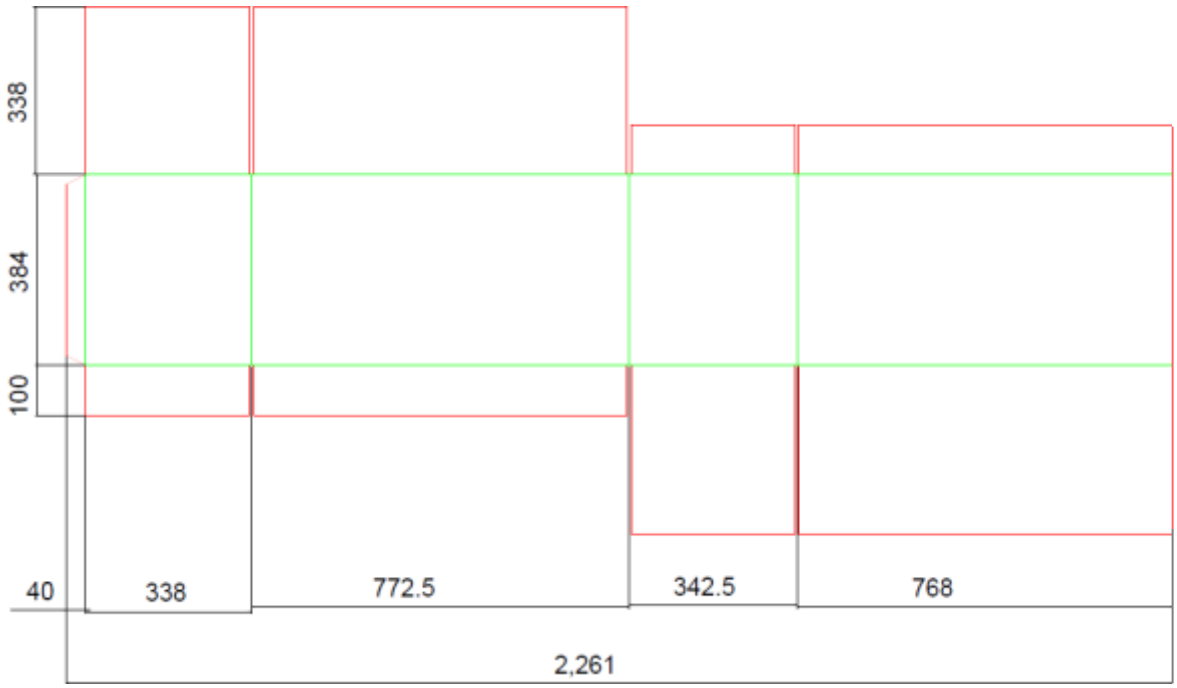
Vase water	Ambient (30℃)		Controlled (15℃)	
	Vase life (days)	Growth of flower diameter	Vase life (days)	Growth of flower diameter
Proposed formula (glucose 2% aluminum sulfate 200ppm sodium hypochlorite 100ppm)	7	305% (max. 104mm)	9	208% (max.80mm)
Reference model (*My Roses*)	7	232% (max. 87mm)	9	203% (max. 87mm)
(*Chrysal BARA for growers*)	5	198% (max. 69mm)	7	157% (max. 57mm)
Control (water only)	5	159% (max. 61mm)	7	163% (max. 65mm)

Note: Tests conducted in February 2016. Samples were transferred from Benguet to Manila in dry condition at 13℃ and then soaked in the solution through the end of the vase life.
My Roses is a product of Sumitomo Chemical Garden Products Inc. based in Japan. *Chrysal BARA for growers* is a product of Chrysal Japan Ltd. under license by Chrysal International B.V. based in the Netherlands. *Chrysal BARA for growers* is prepared for pre-treatment and lacks sugar contents, which explains its less effectiveness for vase life extension and flower growth.

(4) Effectiveness of use of corrugated box for transportation for reduction of damages during the transportation

1) Proposed transport packaging

Figure 3-3-1 provides the drawing of proposed transport packaging for cut rose. The proposed packaging was developed in reference to a practice widely seen in Japan that one of the paired inner flaps was lengthened to protect the flowers. Vertical placement is proposed to minimize the mechanical damage during transportation.



Source: Prepared by the "Project for Enhancing the Competitiveness of Fresh and Semi-processed Agricultural Products through the Application of Appropriate and Sustainable Packaging Technology"

Figure 3-3-1 Structural Design of Proposed Transport Packaging for Roses

2) Verification of effectiveness

A field trial to transport roses from Benguet to Manila under customary conditions was conducted to verify the effectiveness of the proposed packaging. The cases that applied the vertical placement method had no rejects caused during transportation. The case of horizontal placement method with crumpled newspaper cushion at the bottom also avoided causing any rejects after arrival in Manila, although the number of minor damages was higher than in the cases of vertical placement.

Table 3-3-4 Damages during Transportation of Cut Rose

Transport packaging	% Rejects in pieces	Damage frequency
Proposed packaging BC-fluted corrugated fiberboard box Vertical placement (3 bundles × 2 rows)	0%	16.7%
Comparison BC-fluted corrugated fiberboard box with crumpled newspaper cushioning at bottom (T 40mm) Vertical placement (3 bundles × 2 rows)	0%	16.7%
BC-fluted corrugated fiberboard box with crumpled newspaper cushioning at bottom (T 40mm) Horizontal placement (3 bundles × 4 alternating layers)	0%	20.1%
BC-fluted corrugated fiberboard box Horizontal placement (3 bundles × 4 alternating layers)	1.4%	38.2%

Note: Field trial (transportation of the sample roses on 10-ton truck from the farm in Benguet to the PTD in Metro Manila) conducted on May 4, 2016, which was one day after harvesting.
Damages include fallen leaves, fallen petals, broken stems, and broken necks. Broken stems and broken necks are regarded as rejectable.

3.4 Remaining Issues and Recommendations

For further improvement of post-harvest practice and distribution of cut-flowers, following are recommended, in addition to the dissemination and promotion of the proposed improvement:

1. Since distribution and storage at low temperature is the best way for preservation of freshness of cut flowers by suppressing respiration and transpiration of them, pre-cooling and cold chain system should be promoted;
2. Development of sustainable and trustful business relationship with customers should be promoted so that the customers appreciate the efforts for improvement of producers (growers), which can be evaluated only through continuous business transactions, such as efforts for prolonging freshness preservation period, etc.;
3. Close communication and collaborative activities should be promoted among distributors and producers (growers and growers' cooperatives, etc.) targeting joint penetration into the higher level of markets; and
4. Considering the fact that growers have difficulty to harvest the flowers at the best timing of sale, because of the inconsistent and ununiformed growth of the flowers which was caused by inhomogeneous soil conditions of the farm, improvement of the soil condition is strongly recommended for improved income of the growers. With improvement of the soil conditions, growers will become able to plan the right timing of planting to harvesting and shipping in advance.

Part 4: Sweet Potato (Ver. 5.0)

4.1 Current Practice and Need of Improved Post-harvest Handling and Packaging Technologies

(1) Current post-harvest and distribution practice

Table 4-1-1 outlines the current post-harvest and distribution practice of sweet potato:

Table 4-1-1 Current Post-harvest and Distribution Practices of Sweet Potato

Current practice			Remarks
Harvesting / sorting		Plow the field with buffalo	Difficult to harvest by hand because of hard soil
		Throw harvested sweet potatoes to the gathered pile	Sort into acceptable grade and rejects
		Push into the reused woven polyester sack (90kg) for transportation	
Post-harvest treatment			No storage
Transport and distribution	Acceptable grades	In reused sack (90-100 kg), with potato leaves covering the top	The potato leaves are used for protection of the content from direct sunlight and heat
	Rejects (feed grade)	Chipped, dried on the road, and collected on site by the buyer	Additional earning from the once wasted
Washing (at wholesalers)		Step on the potatoes in a metal barrel of water or manually brush off dirt	

Source: Prepared based on the results from field survey conducted in April 2013 in Tarlac

1) Market, distribution, consumption preference for sweet potato

Sweet potato (at least in Tarlac, the current target area) is a commodity which is not much regarded as much among many vegetables / agricultural products from the viewpoint of market circulation. According to a major agricultural product dealer, who has relationship with many supermarkets, importance of sweet potato is 27th among 290 kinds of vegetables on the basis of consumer's purchase amount. Also, at the supermarket, sweet potatoes currently offer only one divisional unit as a management unit (all sweet potatoes are only “sweet potato” regardless of size, other differences). However, as a dealer, consumers prefer medium-size, and it seems that consumers will be more welcome if the sugar content increases.

Moreover, in retail stores such as supermarkets, it is displayed in an inconspicuous situation on the lower shelves. Consumers are not conscious of scars on sweet potatoes,

while they are sensitive to scars on potatoes because potatoes without scars are widely distributed.

2) Production of sweet potatoes

On the other hand, the producing area is not adequate for sweet potatoes due to soil conditions. Sweet potatoes are produced as second crop of paddy in the Tarlac area. However, the yield here is as high as 30 ton/ha, while there is large variation in the Philippines from 6 ton/ha to 41 tons/ha. (About 25 tons/ha in Japan)

The farmer's garden delivery price varies depending on the variety, but the carrot sweet potato is 1,000 pesos/bag of 90 kg, Taiwan variety, which is the sweetest, is about 1,500 pesos/bag of 90 kg. These prices fluctuate depending on whether it is a high season or not. When the price drops under 500 pesos/bag of 90 kg, farmers process the potatoes into chips by drying sweet potato slices on the road and sell them as animal feed. Rejected ones are also sold as dried feed chips as well.

3) For export as raw materials of processing

Some portion is exported to Japan after primary processing as processed raw materials. From the viewpoint of this processed raw material, it is pointed out that the yield ratio is low due to many scars.

Small scars are recovered by curing. With bigger scars, trimming is more necessary, which leads to an increase in loss. They have warehouses to store for 4-5 days, but the damaged ones rot even during that time. Discoloration and rotting start from the rubbed part of the skin, and they have to peel the skin deeply to remove the susceptible part. Therefore, the discarding rate increases and the yield rate gets worse. In Japan, the disposal rate is from 20-25% of the total amount, but it is from 40-50% in the Philippines. The causes of disposal potatoes are mainly abnormal roots and many insect bites in the Philippines.

Potatoes for processing are not matured due to storage costs. Buyers do not evaluate it even if it is matured at a cost. The demand for imported agricultural products in the Japanese market is only low price. They prefer domestic products if they need high quality agricultural.

Sweet potatoes for processing are prepared through washing, peeling, cutting, chamfering, frying, cooling it to ambient temperature and finally freezing. It is shipped 2.5 kg each in a plastic bag (such as nylon/PE) and sealed, packed in 4 bags in a corrugated box (= 10 kg). The freezing temperature is -25 °C. The import tariff from

the Philippines to Japan is 2% in the case of fried potatoes. Compared to 7% in Indonesia and 8-9% in Vietnam, the Philippines has advantage.

Cuts, bruises or other damages caused by improper harvesting and handling were observed on the sweet potato sold at supermarkets.

Sweet potato field in Tarlac. The soil is very hard. Ordinal instruments cannot be used. Plowing the hard field with buffalo

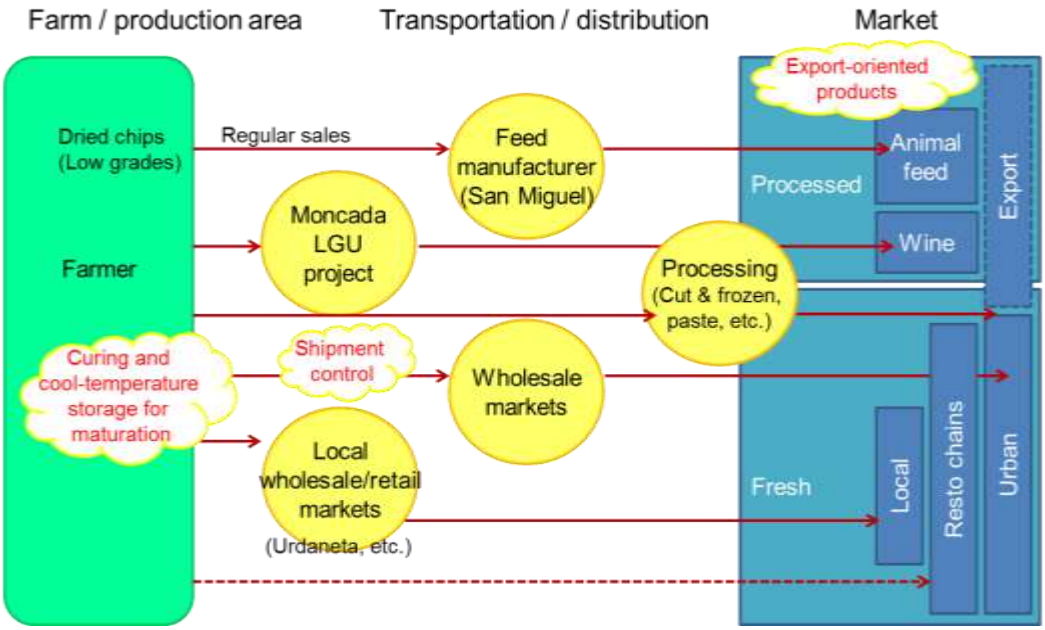
Harvest of sweet potatoes in Tarlac

The top of 90-kg reused sack is covered with leaves for protection

Even badly damaged sweet potatoes are sold in super market.

Even sweet potatoes to be shipped have bruise and blemishes on the surface at harvesting.

(2) Distribution of sweet potato from Tarlac and emerging needs



Source: Prepared based on interviews conducted in April 2013 with sweet potato farmers in Tarlac.

Figure 4-1-1 Distribution of Sweet Potato and Emerging Needs

(3) Issues and needs of improvement in the post-harvest and distribution process of sweet potato

More than 45% of sweet potato harvested is sold for animal feed at low prices, because of insect damages and/or mechanical damages during harvesting process. The rest is also low in value due to poor sweetness and unattractive appearance with many bruises on the surface.

At the same time, farmers harvest and ship during harvesting season regardless of the market price, because there is no storage facility in the production area. For this reason, shipments are concentrated at a harvest season, and the market price is further depressed.

Based on the above facts, the following are the targets of improvement of the post-harvest and distribution practice of sweet potato.

1) Improvement of cut, bruises and blemishes on the surface with careful handling and curing

Since the soil is very hard, the field is harrowed with water buffalo before harvesting, resulting in damages of sweet potato. Mechanically damaged sweet potato is not only bad in appearance but also the cause of higher respiration rate, resulting in high sugar consumption during storage and distribution (and therefore, poor sweetness). Storing of sweet potato for curing under ambient (25-30ºC) for several days will also contribute to reduction of damages.

2) Increase in sweetness with maturing

An opportunity for higher value of sweet potato has been missed without storing the harvested sweet potato at controlled temperature and humidity for increased sweetness and better texture, as practiced, for example, in Japan. Storing of sweet potato for maturing for several months at 13 ºC will increase the sweetness of the sweet potato.

3) Encourage storing at the production site

Sweet potato farmers currently have no choice but to take low prices at the peak season without any means to control shipment. Storing the harvested sweet potatoes in the production site, farmers will be able to avoid concentration of shipment at the harvest season and take advantage of price increase later on.

4.2 Technology for Preserving Freshness of Sweet Potato

In the case of sweet potatoes, respiration and transpiration are not noticeable compared to leaf vegetables, but the necessary condition for long-term preservation is basically the same as that of vegetables and fruits. That is, preserving at low temperature is basic approach to freshness keeping. In addition, sweet potatoes have a function to self-heal scars on the surface. After-ripening of sweet potato increases the sugar content. Therefore, in order to maintain the freshness of sweet potato and increase the commercial value, the following methods should be considered.

- ✓ Prevent the occurrence of scars on the surface by improving harvesting methods, handling methods after harvesting, etc. For example, you can temporarily store sweet potatoes again before shipping for the healing (curing) of wounds at harvest. Furthermore, ripening (maturing) is carried out to raise the maturity and increase the sugar content.
- ✓ During distribution, you can improve packaging containers for storage and distribution, and prevent scars that occur in the distribution processes (especially load handling, transportation, cleaning).

On the other hand, methods of adjusting the composition of the environmental gas are not basically adopted in practice.

Attention should be paid to sweet potatoes that low temperature injury are likely to occur at low temperatures below 12 ºC, and carbon dioxide injury are likely to occur in sealed packaging.

Table 4-2-1 shows the relation between freshness preservation methods for sweet potato and expected results.

Table 4-2-1 Freshness Preservation Methods for Sweet Potato

Method	Purpose	Expected result
1) Preservation and distribution in low temperature	Decrease respiration	To prevent deterioration of product appearance by consuming sugar etc.
	Prevent growth of microorganism	To prevent growth of mold
2) Curing	Formation of cork layer against scars on the surface	
3) Maturing	Provision of carbohydrates	To increase sugar contents

Source: Prepared by the JICA Project Team

4.3 Proposed Improvement of Post-harvest Practice and Packaging Development

4.3.1 Improvement of Handling Practice at Post-harvest and Distribution Process to Reduce Mechanical Damages

(1) Proposed methods of improvement

Following are the methods proposed for reduction of mechanical damages in the harvesting, post-harvest and distribution process.

1. Avoid throwing sweet potato at harvesting
2. Use plastic crates at harvesting
3. Use plastic crates in replacement of sacks for storage and transport.

Reference model (practice in Japan):

Sweet potatoes are harvested by hand without using digging equipment or plowing by oxen. Plastic containers are used for harvesting and transporting sweet potato.

(2) Verification of effectiveness

1) Reject rate at harvest (Current practice)

More than 40% of harvested sweet potatoes were rejected because of mechanical damage, insect damage, or small/over size, regardless of the difference in the practice of collection, as shown in Table 4-3-1.

Table 4-3-1 Rate of Rejected Sweet Potatoes at Harvest

		% in pieces	
		Current practice of collection	Use of crate for collection
Total harvested		100.0	100.0
Total rejected		41.7	42.9
of which:	Mechanical damage	21.9	20.1
	Insect damage	8.4	10.8
	Small/over size	11.5	12.1

Source: Verification trials conducted by the PTD Team.in January and February 2017.

2) Effectiveness of use of crate at the harvest and transport

The occurrence rate of bruise among the food grade alone (or after excluding the rejects) is as follows:

Table 4-3-2 Bruise Observed on Acceptable-quality Sweet Potatoes

Case	Type of package used		% among total food grade	
	Collection after harvest	Transport	Class 1	Class 1 & 2
Current practice	Sack	Sack	0	3.1
Use of crate (current handling manner)	Crate	Sack	0	4.2
	Crate	Crate	28.3	100.0
Use of crate (Careful handling manner)	Crate	Crate	60.4	100.0

Note: Sweet potatoes were classified according to the degree of bruise as shown below.
Source: Verification trials conducted by the PTD Team.in January and February 2017.

Class 1: up to 10% of the surface is bruised
Class 2: up to 25% of the surface is bruised
Class 3: over 25% of the surface is bruised

Class 1 Class 2 Class 3

Current practice means throwing of the produce in piles in the field after harvesting, and packed in sacks. According to this data, use of crate for harvest alone is not necessarily effective for reducing bruise. In other words, careful handling in collecting the produce without throwing it to piles is also significant.

Use of sack for transportation is the major factor of cause of bruises, and brushing increases bruises further. If crate is used for transportation, the cause of bruises can be reduced even with use of brush in washing.

(3) Assessment of viability of the proposed technology and method

With introduction of plastic crates to the processes of harvest, transportation and distribution, replacing the currently used packaging of PP (polypropylene) woven sack, opportunity loss due to low market prices because of the poor merchantability is expected to be improved.

As a result, the sales amount is expected to be increased by 14%, assuming the sales prices and harvest volumes by grade as follows:

- Grade 1: P. 14.9/kg
- Grade 2: P.13.5/kg
- Grade 3: P. 11.0/kg

For detail, see Table 4-3-3.

(% of harvest volume by product grade)

	Grade 1	Grade 2	Grade 3
Current practice (*1)	0	3.1	96.9
Proposed (*2)	28.3	71.7	0

Notes: No-food grade product of insect damage and mechanical damage in harvest process, which accounts for 42% of the total harvest, is excluded from the above table.

(*1): Use of PP woven sack
(*2): Use of plastic crate

4.3.2 Application of Curing Process for Recovery of Damaged Surface

(1) Proposed method of improvement

Curing under ambient for short period (one week) is recommended.

(2) Verification of effectiveness

The bruise occurrence rate decreases in longer curing period in the case of careful washing, while it increases in the case of brushing.

Table 4-3-4 Bruise Reduction by Curing and Careful Washing

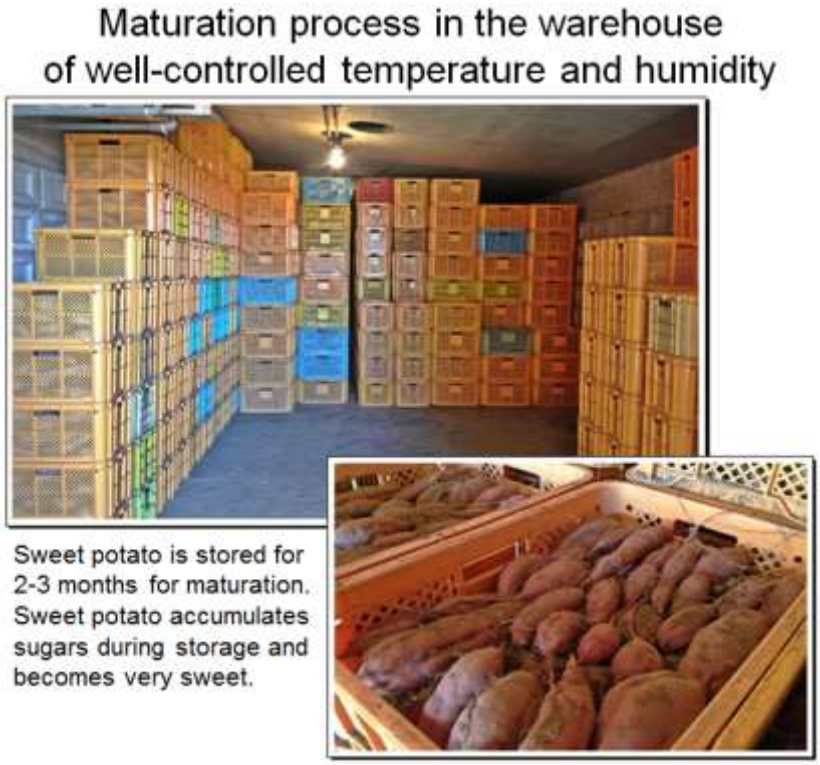
Washing method / Curing period	Bruise occurrence rate by curing period and washing method (% of total food grade)	
	Careful washing	Brushing
7 days	11	
10 days		18
13 days	5	23

Source: Verification trials conducted by the PTD Team.in January and February 2017.

4.3.3 Increase in Product Value by Maturing and Adjustment of Shipping Timing

(1) Proposed method of improvement

Application of low-temperature storage for increased sweetness and adjustment of shipping timing are recommended. By storing in warehouse at the production site at a controlled temperature of 13-15ºC for 2-3 months for maturation, sweet potato accumulates sugar contents and become more sweet and soft. In addition, shipment control of the product is also effective.

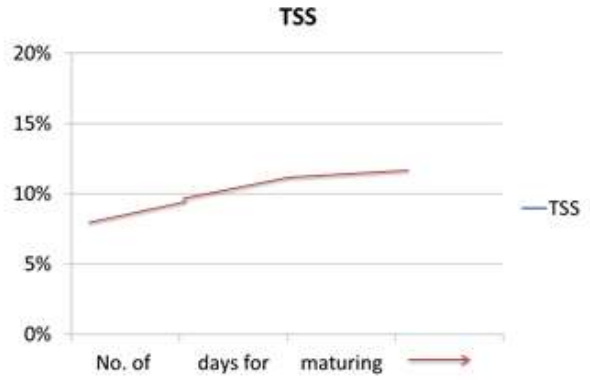


Source: JA-Namegata (http://www.ja-namegata.or.jp/), data retrieved on May 13, 2014. Translation by the JICA Project Team

Figure 4-3-1 Controlled Temperature and Humidity Storage for Maturation

(2) Verification of effectiveness

The sugar contents increases gradually during low temperature storage. However, if the storage temperature is higher than 16 ºC, it will result in sprouting. Low temperature of 13 ºC makes long-term storage of sweet potato possible.



Source: Verification trials conducted by the PTD Team.

Figure 4-3-2 Total Soluble Sugar Increase with Maturation

(3) Assessment of viability of proposed technology and method

Improvement of palatability of the sweet potato with applying maturing process is expected to result in increase in the sales price. In addition, adjustment of the shipping timing from the period in harvest season to after harvest season by taking time for maturing is also expected to contribute to increase in the sales price.

- Sales price in season: P. 500/90kg
- Sales price after season: P. 1,000/90kg.

4.3.4 Development of Packaging Graphic Design

(1) Development target of the graphic design of the packaging

Sweet potato in the Philippines is considered as a poor man's crop. The development of the graphic design of the packaging was conducted to uplift its value by making presentable packaging and making own brand that may give the consumers a new mindset that sweet potato is an important part of the diet.

To establish a local brand, original brand name and layout for differentiation were developed. The proposed brand, chosen in discussion with the focused group, is "Mighty Kamote", which targes kids to be willing to eat kamote since it has nutritional values which make them stronger and healthier. Actually, health-conscious people are apt to eat sweet potatoes in the Philippines.

There are some varieties of sweet potatoes in terms of appearance and fresh. Color variation was developed using different colors of ink to distinguish each other based on the common pattern. At first, ube (purple), kahel (orange), dilaw (yellow), and puti (white) were developed. However, to make it a generic one, it was decided to focus on one image using white and decided to use colored stickers for the other types.

Also adopted is brown color type of box to prevent packaging from getting dirt since white box is easy to get dirty. The transportation box is intended to be used for shop display, also.

A sales copy was added to the label to give focus on what the product gives or what are possible benefits on the body when eaten. Differentiation to add value was tried by presented characteristics of the product in the phrases.

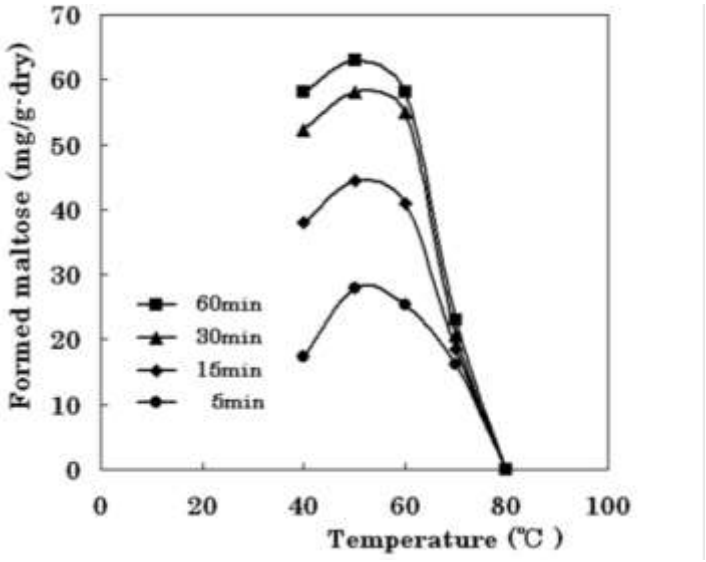
(2) Verification of effectiveness

The new designed boxes were highly appreciated in TWG, which was held on May 18, 2016, by participants such as members of cooperatives and so on.

4.4 Remaining Issues and Recommendations

(1) For ensuring the effects of the improvement methods

1. In addressing these countermeasures, it is necessary to improve the merchantability (value) of sweet potato itself. It is not possible to spend cost on countermeasures where purchase price is low. Therefore, for this purpose, it is necessary to propose and exploit consumption scenes of high-value sweet potatoes, thereby increasing the merchantability of the sweet potatoes as the raw material. In addition, regional brand development should also be considered in order to have a good evaluation from the market for sweet potatoes with a good appearance and sweetness.
2. In implementing these countermeasures, not only producers (and their organizations) should operate alone, but also collaboration for product development with distributors having certain established distribution channels, sweet potato processors (or importers etc.) and business consumers with a certain scale demand will be effective to improve productivity.
3. Sweet potato contains a lot of thermostable amylase, so that the preservation (maturing) helps to increases sugar content and steaming and roasting also increase in the course of heating. It is known that the sugar content rises slowly through a temperature of 60 to 70°C, as shown in Figure 4-4-1. This point is considered in Japan in the processing of steam and roast sweet potatoes. Also, how the sugar content increases on which condition, such as temperature, season, etc. depends on the product varieties. Even cheap varieties with low sugar content are expected to add value if sugar content rises greatly during storage.



Source: Kiyotaka Maenami, "Denpun oyobi Toshitsu wo Oku Fukumu Syokuhin no Kanso Kiko no Kaimei to Teion Choshitsu Kanso Gijutu no Kaihatsu ni-kansuru Kenkyu [Study on Clarification of Drying Mechanism of Starch and Sugar Rich Foods and Development of Drying Technology under Low Temperature and Controlled Humidity]," 2005.

Figure 4-4-1 Effects of Temperature and Reaction Time on Maltose Formation by Using β-amylase

(2) Improvements in agricultural practice

At harvest, [1] mechanical scars caused by using an oxen-drawn plow and product damage (crack), [2] scars due to insect damage, etc. are also likely, but these are out of the scope of the project. For example, to stop oxen plowing, soil must be so soft that digging and harvesting is possible.

2　普及用ガイドブック

2.1 ドリアン

Packaging Technology Development Project for Fresh and Semi-processed Agricultural Products in the Philippines

Packaging Development for

Durian

Packaging Technology Division (PTD)
Industrial Technology Development Institute
Department of Science and Technology
With technical cooperation of
Japan International Cooperation Agency (JICA)

The primary objective of this Project

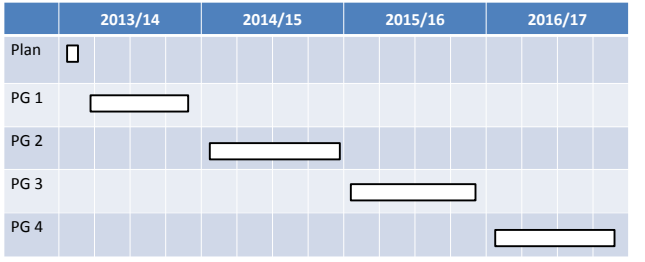
Building the technological capacity and mechanism
- to apply appropriate and sustainable packaging technologies
- for fresh and semi-processed agricultural products in the Philippines

Enhance the competitiveness of these products, through:
- Reduction of loss in the post-harvest and distribution processes,
- Preserving freshness, and
- Adding values.

Organizational setup for Project Implementation

- PTD Project Team
- Networking with other government agencies/institutes
- Organization of the local stakeholders on the site for positive involvement in the packaging development process

Overall Process of the Project



PG: Product Group

Issues of current practice and needs for packaging development (1)

Current practice	Function of the practice	Needs for packaging development
Frozen durian - Small-size packaging of the flesh using plastic wrap, pouch, tray, and/or container - Long-term frozen storage of the packaged durian flesh	1) To preserve the product longer and avoid to sell it at depressed market prices in the season 2) To provide easiness of handling and eating 3) To reduce the strong aroma during storage and hand-carrying	1) Improve the flavor-barrier properties for the consumer to carry it without restriction 2) Improve packaging operation to prevent possible damages to the package

Issues of current practice and needs for packaging development (2)

Current practice	Function of the practice	Needs for packaging development
Frozen durian - Styrofoam box for transport packaging - Styrofoam box for carry-out packaging for the consumer	To keep the product frozen for: 1) Long-distance transport 2) Carrying out by consumers	1) Increase the cold-keeping capacity to meet requirements by destination 2) Improve efficiency and attractiveness of hand-carrying box

Issues of current practice and needs for packaging development (3)

Current practice	Function of the practice	Needs for packaging development
Fresh durian Corrugated box with aeration holes for long-distance transport	To prevent fresh durian from damage due to mechanical shock and vibration and insufficient aeration in the transportation process	1) Determine appropriate strength of the box for the fruit having heavy and hard husk 2) Improve provision for efficient manual handling of the heavy transport package

Summary of packaging development conducted

	Proposed development
(1)	Flavor-barrier packaging
(2)-1	Hand carrying box for the packaged frozen durian of (1)
(2)-2	Transport packaging for the packaged frozen durian of (1)
(3)	Transport packaging of fresh whole durian
(4)	Promotional consumer packages to explore/develop untapped consumer markets

1. Flavor-barrier packaging for frozen durian

Current practice

Frozen durian packaged in a polystyrene container

Frozen durian double-packaged with wrap film and a pouch

Foamed polystyrene container for frozen durian

Issues to be addressed

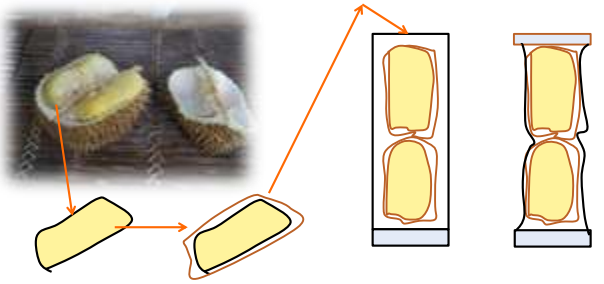
- While freezing is a good way to suppress the strong aroma, the aroma resumes as once frozen durian is thawed.
- Even while durian is kept frozen, the aroma can migrate to other foods in the freezer.

Objective of packaging development

- The packaging development is intended for materializing odor-free frozen durian products by packaging durian flesh with materials proven for the high flavor barrier properties, and thus cultivating the potential demand for durian fruit.
- The packaging materials must be freeze resistant.
- The flavor-barrier packaging, which allows very low gas permeability, will suit only for frozen storage, for the fruit would get translucent in color and change the flavor under the anaerobic condition due to its high rate of respiration.

Output of the packaging development

Packaging method



1. Wrap with film and quick-freeze
2. Fill in a pouch
3. Vacuum-package

Research Report

Flavor-keeping/Odor-barrier Packaging of Durian

Objective:

•To evaluate selected flexible films for its flavor keeping property when used as primary and secondary packaging for fresh and frozen durian.

Expt. 1 . Double wrapping with twisting

Sample Preparation	Packaging Material		Storage Condition*
	Primary Packaging	Secondary Packaging	
Fresh	PE wrap	ON/PE	Chilled & frozen
		ON/PVDC/LLDPE	Chilled & frozen
	PVDC wrap	ON/PE	Chilled & frozen
		ON/PVDC/LLDPE	Chilled & frozen
Frozen	PE wrap	ON/PE	Chilled & frozen
		ON/PVDC/LLDPE	Chilled & frozen
	PVDC wrap	ON/PE	Chilled & frozen
		ON/PVDC/LLDPE	Chilled & frozen

Results:

- After 6 months storage at freezing temp. (-20°C), there was no migration of smell using PVDC & wrapping films. However, there was film cracking observed on primary packaging (ON/PVDC/LLDPE).

Expt. 2. Double wrapping with heat sealing

Sample Preparation	Packaging Material		Storage Condition*
	Primary Packaging	Secondary Packaging	
Frozen	KON	ON/LLDPE	Frozen
	KON	KON/LLDPE	Frozen
	KOP	ON/LLDPE	Frozen
	KOP	KON/LLDPE	Frozen
	HDPE	ON/LLDPE	Frozen
	HDPE	KPN/LLDPE	Frozen

Results:

- Primary packaging film was center heat sealed and two ends of the pouch were twisted. Samples were vacuum packed in secondary package. After 6 months of frozen storage, slight migration of durian odor was observed.

Expt. 3. Double wrapping with vacuum packing

Sample Preparation	Packaging Material		Storage Condition*
	Primary Packaging	Secondary Packaging	
Frozen	HDPE	ON/LLDPE + vac.	Frozen
	HDPE	KON/LLDPE + vac.	Frozen
	KON + vac.	ON/LLDPE + vac.	Frozen
	KON + vac.	KON/LLDPE + vac.	Frozen

Results:

- Primary and secondary packaging were vacuum sealed. After 2 months of frozen storage (-20°C), there was no migration of durian odor for samples vacuum packed in KON + KON/LLDPE.

2 Hand-carrying box for packaged frozen durian

Current practice

Ice Cream Box
40 times expanded EPS foam box
L230xW230xH175, T: 12

Fillet Box
40 times expanded EPS foam box
L320xW200xH140, T: 20

Issues to be addressed

- Current carrying box, which is a styrofoam box without a handle, is bulky compared to the content and inconvenient for the consumer to carry around with.
- When the newly-developed flavor-keeping packaging technology is introduced, there will be a need to visually present the benefits of the packaging technology to promote adoption, and the carrying box will be part of the communication media.

Objective of packaging development

- Develop an efficient hand-carrying box of good cold-keeping properties that keep the content frozen up to 24 hours for the convenience of international tourists
- Verify the cost-effectiveness of water-proofed corrugated fiberboard as it is known for better cold-keeping properties
- Verify the cost-effectiveness of cooling agents to prolong the frozen temperature

Research Report

Frozen Durian

Cold-keeping properties for frozen durian

Measure the cold-keeping capacity through monitoring the temperature change over time

Frozen Durian

Cold-keeping properties for frozen durian

Test Conditions

- **Measuring equipment: Temperature sensor**
- **Environmental temperature: 28 ℃ - 30 ℃ (Actual≒26 ℃)**
- **Content temperature at the beginning: strictly -18 ℃**
- **Cooling agent: Verification on cold-keeping effects (with or without)**
- **Test Method: Reading the hourly temperature recorded on the sensor after 24 hours**

Frozen Durian

Cold-keeping properties for frozen durian

Results: Measured temperature in ° C

TYPE	30 min.	1 hour	2 hours	4 hours	8 hours	10 hours	12 hours	15 hours	20 hours	24 hours
EPS Foam Ice Cream Box with cooling gel	-8.8	-8.2	-7	-5.6	-3.7	-3	-2.1	-1.4	0.2	3.8
EPS Foam Ice Cream Box	-0.3	0.5	1.9	3.8	6.4	7.7	9.2	11.5	15.2	18.2

The cooling agent increased the cold-keeping capacity of the container. This can be used to tap export market.

3 Transport packaging of packaged frozen durian

Current practice

Super Box
EPS foam box
(40 times expanded
Inner dimension: L400xW400xH420 T20
Content: Frozen durian 50 packs/box GW: 27 kg)

Issues to be addressed

- EPS foam boxes require space even when they are not used for the purpose of transportation.
- It is difficult to obtain an EPS box of exact form and size for a certain quantity of the product, which undermines the cold-keeping capacity of the container.
- A collapsable corrugated box can be a better substitute as long as it provides equivalent heat insulation.

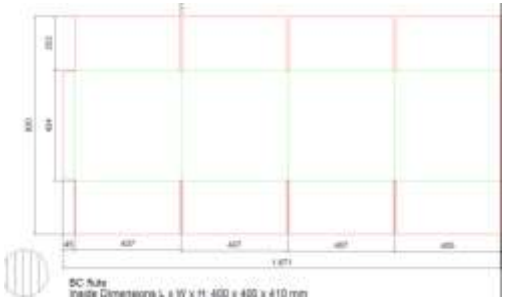
Objective of packaging development

- Develop a corrugated box for transportation of the packaged frozen durian with cold-keeping properties sufficient to keep the product frozen for up to 24 hours

Packaging method

Transport packaging

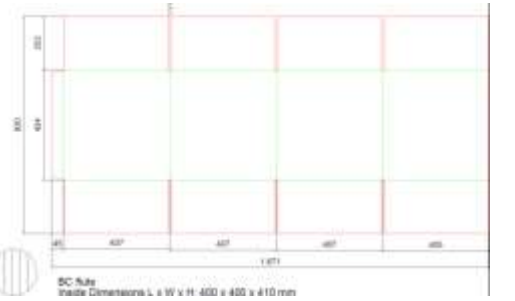
a. Wax-coated corrugated fiberboard



Packaging method

Transport packaging

b. Non-coated (regular) corrugated fiberboard



Research Report

Type of carrying box	Cooling agent	Location	Time (hour) and Temperature (°C)												Change /hour
			0	0.5	1	2	4	8	10	12	15	18	20	24	
a. Corrugated box (wax-coated) L400×W400×H410 [50 individual packages]	0	Top	8.3	-18.2	-15.8	-12.1	8.5	-4.2	-1.1	11.0h -0.1	3.2	7.3	8.8	11.3	1.72
		Middle	-0.1	-22.1	-21.6	-20.3	-17.5	-13.2	-11.8	-10.7	-9.3	-8.1	-7.4	-6.1	0.68
		Bottom	2.9	-21.8	-21.2	-20.0	-17.4	-12.8	-11.2	-10.0	-8.6	-7.5	-6.7	-5.8	0.68
	4	Top	29.4	-20.3	-18.5	-15.5	-11.4	-7.9	-6.4	-4.6	-1.8	-0.8	1	8.6	1.12
		Middle	5.7	-18.1	-17.9	-17.3	-15.6	-12.0	-10.8	-9.8	-8.5	-7.6	-7.0	-5.7	0.53
		Bottom	11.1	-17.2	-16.0	-14.2	-11.8	-8.9	-7.9	-7.0	-6.0	-5.1	-4.4	-2.5	-.62
b. Corrugated box L400xW400xH410 [50 individual packages]	0	Top	16.5	-11.0	-8.5	-5.5	-1.5	5.5h 0.0	3.5	8.0	12.5	14	15	17	2.00
		Middle	3.4	-2.1	-20.8	-19.2	-16.1	-11.6	-10.1	-8.7	-7.4	-6.1	-5.1	-3.1	0.76
		Bottom	11.1	-17.2	-16.0	-14.2	-11.8	-8.9	-7.9	-7.0	-6.0	-5.1	-4.4	-2.5	0.63
	4	Top	11.4	-6.1	-3	-1.8	-1.1	9.5h -0.1	0.3	3.6	7.2	10.6	13	15.8	1.58
		Middle	5.4	-20.5	-20.2	-19.2	-16.3	-12.2	-10.9	-9.9	-8.5	-7.5	-6.9	-6.0	0.62
		Bottom	15.1	-21.0	-20.1	-18.4	-15.6	-11.5	-10.1	-9.1	-7.9	-6.9	-6.2	-5.4	0.66

4 Transport packaging for fresh whole durian

Current practice

Corrugated box
BCf, with cross partition
Internal dimension: L400xW400xH420
Content: Fresh Durian 4 pcs/box GW: 13 kg

After transportation from Davao (producing area) to Manila (PTD):

- **Hand holes have been broken.**
- **The fruit has swung and changed the orientation.**

Issues to be addressed

- The actual transportation test revealed that current transport packaging does not satisfy the strength required for efficient handling of heavy load, as indicated by:
  - Breakage of the hand hole
  - Swing and shift of the fruit inside the container

Objective of packaging development

- Improve the handle strength to support the load weight of up to 30 kg
- Adjust the size of box to minimize swing of the fruit and to save volume of the material

Research Report

Fresh Durian

Hand Holes Reinforcement for Transport Box

Handling tests of corrugated box

1. **Dragging test**
2. **Lifting test**

Fresh Durian

Hand Holes Reinforcement for Transport Box

	13 kg	26 kg	39 kg	51 kg
Without reinforcing board	Ok	Ok	NG	
With reinforcing board	Ok	Ok	Ok	NG

The use of reinforcement pads increased the maximum allowable load the transport box can withstand

Fresh Durian

Partition System for Transport Box

Using partitions to enhance the top load compression strength of the box

5 Graphic design for developed packages

Current practice

4-piece transport package of fresh whole durian

Individual packaging of frozen durian

Hand-carrying box for frozen durian

Issues to be addressed

- The series of durian packages lacks an unified image which is necessary to establish brand recognition.
- Hand-carrying box for frozen durian as well as transport packaging for fresh whole durian does not have any graphic design applied, which miss the opportunity to promote the product in the market.

Objective of packaging development

- Develop graphic design for the durian packages that promotes the positive brand image of Davao durian in the market

Output of the packaging development

4-piece case for transport packaging of fresh whole durian

Individual packaging of frozen durian

Individual packaging of fresh whole durian

Hand-carrying box for frozen durian (EPS foam box + sleeve handle)

Hand-carrying box for frozen durian (Wax-coated corrugated fiberboard)

37

38

39

40

41

42

43

44

45

46

Packaging method & materials

Hand-carrying box
c. EPS foam box with corrugated fiberboard handle

EPS Box Carrier
C-flute corrugated board

Part A

Part B

47

48


DURIAN
"King of Fruits"
PHILIPPINES
High in
POTASSIUM!
Good Source of:
CALCIUM
IRON and
MAGNESIUM
PRODUCT
OF THE
PHILIPPINES
JICA

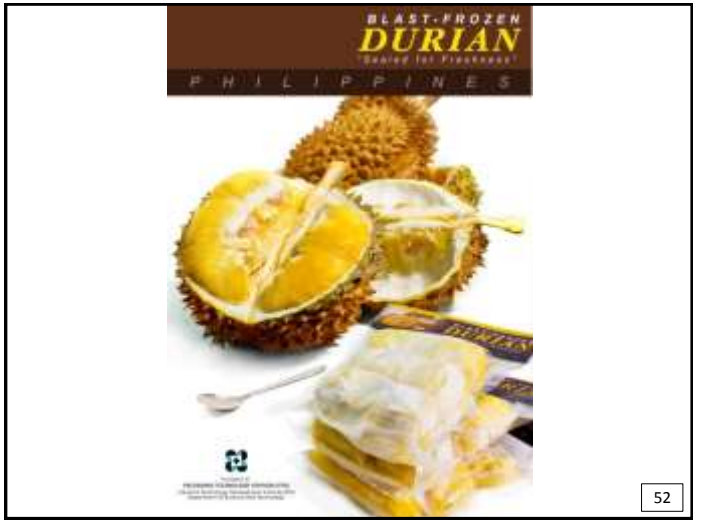
49


FROZEN
DURIAN
PHILIPPINES

50


DURIAN

51


BLAST-FROZEN
DURIAN
PHILIPPINES

52

2.2 燻製魚

Textbook for Application
Ver.8.1

The Processing of Smoked Fish

Six Months Shelf-life under Ambient Temperature

Packaging Technology Division (PTD), ITDI, DOST
With technical cooperation of
Japan International Cooperation Agency (JICA)

Table of Contents

Time Table (Day1)

9:00 – 9:30	**Lecture (1)** ○ Overview/training objective ○ Process/technology on high value smoked fish (process flow) **MORNING SNACKS**
9:40 – 10:00 10:00 – 11:20	**Hands-on** ○ Step 1 – Cutting of fish (20 min) ○ Step 2 – Steaming of fish (1 h) **Demo***
11:20 – 11:30 11:30 – 13:50 (11:40 – 12:30) (12:40 – 13:10)	○ Preparation of marinade solution. ○ Step 3 – Marination (10 min) ○ Step 4 – Drying (2 h) **LUNCH BREAK** **Lecture (2)***
(13:10 – 13:40)	○ "Current issues related to the distribution of smoked fish in the Philippines" (30 min) **Lecture (3)***
13:50 – 15:50	○ Development of the smoked fish product of longer shelf life which can be distributed at ambient temperature (30 min) **Hands-on**
(14:10 – 15:10)	○ Step 5 – Smoking (40 min) **Lecture (4)***
(15:10 – 15:20) (15:20 – 15:50)	○ Prevention of bacterial growth (30 min) ○ Prevention of fat oxidation in the distribution process (30 min) **COFFEE BREAK** ○ Discussion on equipment (30 min)
16:00 – 16:10 16:10 – 16:40 16:40 – 16:50 16:50 – 9:00	**Hands-on** ○ Step 6 – Cooling of smoked fish (10 min) ○ Measurement of water activity (30 min) ○ Step 7 – Packing in PE bags (10 min) ○ Step 8 – Conditioning (16 h)

Time Table (Day2)

8:00 – 9:00	**Discussion** ○ Review of Day 1 activities **Lecture (5)** Reduction of mechanical damage during distribution of smoked fish (20 min) **MORNING SNACKS**
9:00 – 10:20	**Hands-on** ○ Step 9 – Vacuum packaging of smoked fish (20 min) ○ Step 10 – Boil pasteurization of smoked fish (30 min)
(9:40 – 10:10)	**Lecture (6)*** ○ Packaging design for smoked fish (30 min)
10:20 – 10:40	**Hands-on** Step 11 – Removal of boil pasteurized smoked fish from steamer (25 min)
10:40 – 11:40	**Summary and Discussion** ○ Evaluation of smoked fish produced during the training ○ Suggestion for possible improvement of the product for better marketability & competitiveness
11:40 – onwards	**LUNCH**

*Activities to be conducted during the lag/waiting time.

Lecture 1-1

OVERVIEW / TRAINING

Target of the product

1) Ready-to-eat product (*)
2) Good flavor and texture as a higher-value product
3) Longer shelf life without freezing at ambient temperature by preventing
   1. the growth of bacteria and mold
   2. fat oxidation

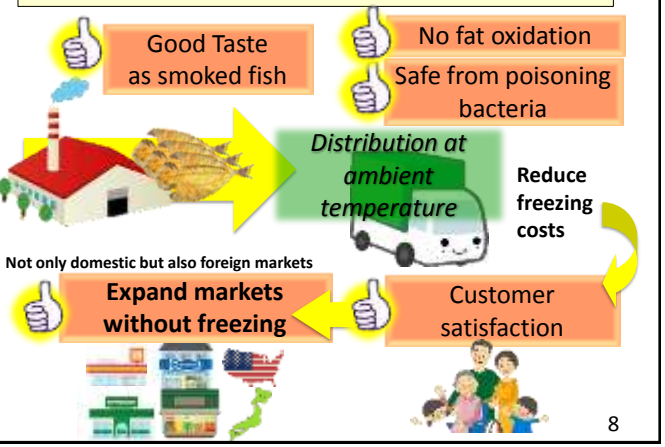
_____

Note: (*) In the Philippines, people eat smoked fish mostly after deep-frying it. However, the target of the proposed products are the new style of smoked fish of ready-to-eat.

How to Achieve Targets

Targets	How to achieve the target
Good Flavor and Texture 	Control water activity (Aw) of the product
	Control pH of the product
Prevent Bacterial Growth 	Control water activity (Aw) of the product
Kill Bacteria, Yeast and Mold	Heat pasteurization after package
Prevent Fat Oxidation	Use of high gas barrier plastic film for individual package with vacuum sealing

Concept Image



Lecture 1-2

PROCESS/ TECHNOLOGY ON HIGH VALUE SMOKED FISH (PROCESS FLOW)

Current processing practice

Cleaning and deboning of milk fish

Heating in brine

Smoking with small smokers

Put the smoked products in ON/PE pouch

Vacuum packaging

Transport at ambient temperature, or frozen. Eat deep fried smoked fish

Final products

Proposed processing flow

Time and temperature here is based on the assumption that the fish is prepared at 100g /piece (Fillet) or about 400g/whole fish. Time and temperature should be adjusted according to size and thickness of fish

Step 1: Deboning and preparing under low temperature

Step 2: Steaming at 85-90℃ for 1 hr. — Steamer with temp. controller

Step 3: Dipping in the seasoning mixture overnight

Step 4: Drying at 70-75℃ for 2 hrs. — Dryer with temp. controller

Step 5: Hot smoking at 80-85℃ for 30-40min. — Smoker with temp. controller

The process to control Aw

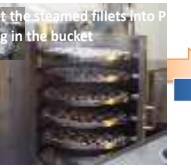
Step 6: Packaged by **high gas barrier** transparent pouch (KON)

Step 7: **Boil pasteurization** at 80℃ for 30min to kill non spore-forming bacteria, yeast and mold

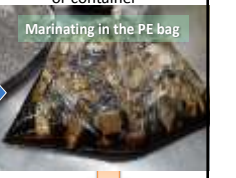
Proposed processing flow (image)

Cleaning and deboning of milk fish

Steaming



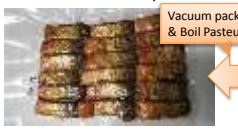
Marinating in PE bag or container



Drying

Smoking

Vacuum packaging & Boil Pasteurization



Transport to the market at ambient and ready to eat

Lecture 2

CURRENT ISSUES RELATED TO THE DISTRIBUTION OF SMOKED FISH IN THE PHILIPPINES

General feature of smoked fish

Smoked fish has following features in general

1) Good flavor with smoking
2) Better preservative quality

Preservative quality was the main feature of smoked fish in the past, but nowadays, good flavor with smoking is considered as the main feature of Smoked Fish as a higher value product.

High quality wood chips should be selected for better flavor and more safety products. Also, preservative quality should be increased by Aw control.

Current issues related to distribution of smoked fish in the Philippines

Short shelf life (3~5 days under ambient temperature)

Low credibility of cold chain

Damage of product during transportation

Transport under ambient temperature

As a result…

1. **Distributing to nearby markets without freezing**
2. **Freezing for distant markets or export**
3. **Not ready to eat; deep frying before eating**

In the case of distribution **with freezing**:

- High costs for freezing
- High costs for frozen transportation
- Unreliable/unstable cold chain ➡ Risk of quality deterioration in the distribution process
- Cooking before serving (not ready to eat)

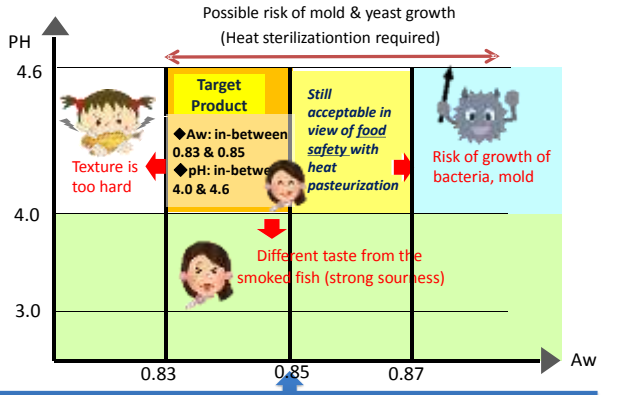
In the case of distribution **without freezing**:

- Short shelf life ➡ Markets are limited to those of short distance only
- Risk of deterioration of the quality in a short time in the distribution process (bacterial spoilage and fat oxidation)
- Mechanical damages on the product during transportation due to over stuffing in carton box, etc.

Lecture 3

DEVELOPMENT OF THE SMOKED FISH PRODUCT OF LONGER SHELF LIFE WHICH CAN BE DISTRIBUTED AT AMBIENT TEMPERATURE

Target level of Aw and pH



Summary : How to achieve the targets of the proposed smoked fish product

Targets	How to achieve the target	Rationale
Prevent Bacterial Growth	Maintain Aw at 0.85 or lower	Spore-forming poisoning bacteria cannot grow on the food of Aw 0.93 or lower. However Aw 0.85 or lower is legally permissible level in the Philippines
Kill Bacteria, Yeast and Mold	Boil pasteurization at 80℃ or higher, and 30 min. or longer	Non-spore forming bacteria, yeast and mold can be killed by hot water pasteurization at 70℃ or higher for 25 min. or longer depending of the size of fish (& pH).

Summary : How to achieve the targets of the proposed smoked fish product (Continued)

Targets	How to achieve the targets	Rationale
Good Flavor and Texture	Maintain Aw at 0.83 or higher	If Aw of the product is lower than 0.83, then its texture becomes harder.
	Maintain pH at 4.0 or higher	If pH of the product is lower than 4.0, then it tastes sour.
Prevent Quality Deterioration	Vacuum-package using high barrier plastic film for individual package	Fat oxidation, non-enzymatic browning, off-odor development occur with presence of oxygen during distribution and storage

Standard Operation Condition and Control Points (CP)

Process	Standard operation condition	At the end of the process		Remarks
		Weight	Aw	
1) Deboning and preparing raw fish	Low temperature shorter time	g	0.99	Need hygienic control
2) Steaming	85-90°C, 1 hr.	g	0.99	Steaming helps to marinate well. About 20 % of drip occurs.
3) Dipping in the seasoning mixture	Overnight under ambient	g	0.92 -0. 89	Aw of mixture: 0.62 Increase the weight but lower Aw due to absorbed salt content
4) Drying	70-75ºC, 2hrs and more if necessary	g	0.89 – 0.85	Dry until Aw become 0.85
5) Hot smoking	80-85ºC, 40min	g	0.85 -	To prevent bacterial growth by lowering Aw to give good flavor
6) Vacuum package with high gas barrier film	Barrier level of film O_2 10cc/m^2·24hrs	g	0.85 -	To prevent fat-oxidation, non-enzymatic browning & off-odor development
7) Boil pasteurization	80ºC, 30min	g	0.85 -	To prevent growth of non-spore forming bacteria, yeast & mold

21

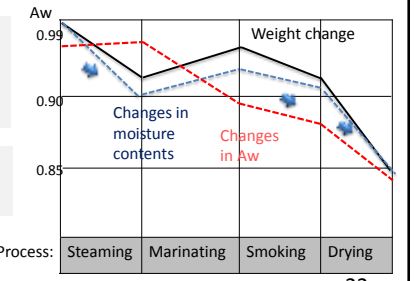
How to prepare the index of Aw using moisture content

Step1 : Measure the weight, the moisture contents and Aw at the end of each process

At the end of process (n)  At the end of process (n+1) 

Step2 : Plot the weight, moisture contents and Aw on the same graph to define the relationship between the weight/moisture contents and Aw

Then, you can estimate the Aw of the product at the end of each process by weighing the product

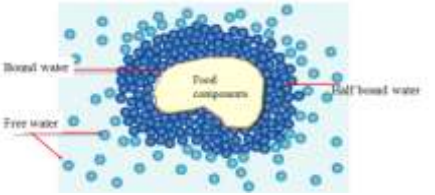


22

What is Aw?

✓ Aw (Water Activity) is the barometer of free water content of foods.

- Free water in food is not bound to food molecules.
- Free water can support the growth of bacteria, yeasts and molds (fungi). The term “water activity” (Aw) refers to this unbound (free) water.
- Moisture content means the total volume of the 3 types of water contained in the material (food)



23

3 types of foods categorized by Aw

Dry Food (DF)	Intermediate Moisture Food (IMF)	High Moisture Food (HMF)
Low Aw		High Aw
Aw. 0.65-0.00	Aw. 0.90-0.65	Aw. 1.00-0.90
• Cookie, Rice cracker, Dried confectionaries, Deep-fried, Vacuum-dried fruits & vegetables, Potato chips, Popcorn, Snack foods, etc. • Instant dried foods (Instant noodle & soup), Breakfast cereal, Dry fruit, etc. • Dried fishery products, Dried milk, Dried meat, Powdered foods (Instant soup, Skimmed milk, etc.) • Green tea, Black tea, Regular & instant coffee, etc.	• Processed IMF (Salty foods, High sugar foods) • Semi-dried traditional foods (Dry fruits, Dried fish & shrimp, Confectionaries, etc.) • Traditional seasonings (Fish sauce, Soy sauce, etc.) 	• Fresh foods (Fruit, Vegetable, Meat, Milk, Egg, Fish, Shellfish, Sea weed, etc.) • Daily necessity foods (Fresh noodles, Bread, Pickles, Tofu, etc.) • High moisture processed foods (Ham & sausage, Fruit & vegetable juice, Cakes, Cooked fishes, etc.) 

24

Lecture 4-1

PREVENTION OF BACTERIA GROWTH

Prevention of bacterial growth

There are 4 types of microorganisms, which should be focused on the view of food quality change

Bacteria	Spore forming (heat resistant) bacteria
	Non-Spore forming bacteria
Mold	
Yeast	

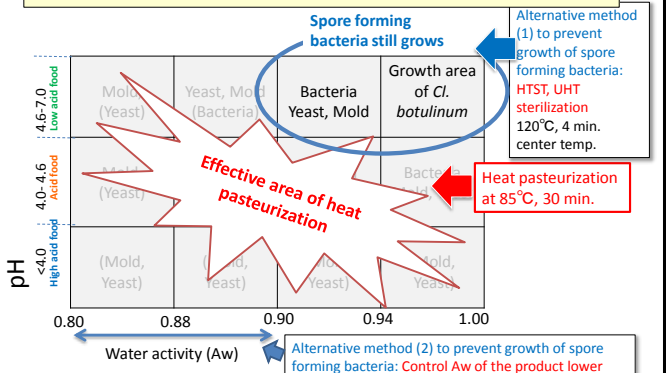
(1) **Non-spore forming bacteria** can be killed by heat pasteurization. **Mold and Yeast** can be killed also by ordinal heat pasteurization.

(2) However, **spore forming bacteria** i.e. ***Bacillus, Clostridium*** cannot be killed by ordinal heat pasteurization. For controlling spore forming bacteria, following methods are used:

1) High temperature short time (HTST) sterilization: **Retort** sterilization technology

2) Controlling of Aw of the product at lower level

Effective area of heat pasteurization



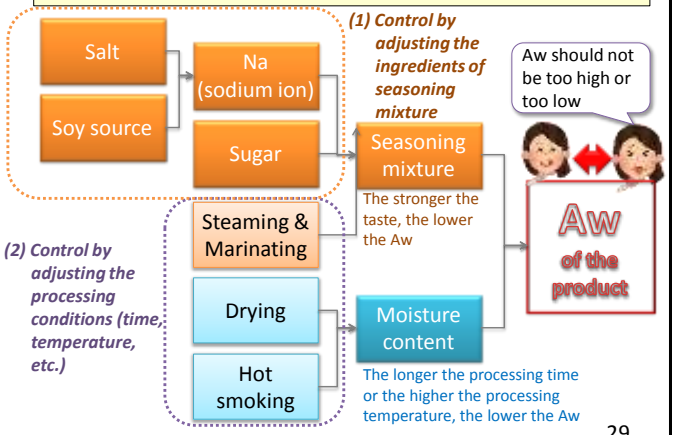
In order to keep the good texture of the product, the heat pasteurization method is used for this proposed smoked fish product. It means that **Aw control is still needed to prevent *Cl. Botulinum* from growing.**

- ✓ Maintaining the Aw of the product at 0.87 or lower is critical for <u>preventing the growth of spore forming type bacteria</u>
  Theoretically no more growth of the spore forming poisoning bacteria at 0.90 or lower Aw
- ✓ Between 0.83 to 0.85 is the recommended level of Aw of the final product, but recommend to keep it close to 0.85 as much as possible to make the product soft, and not too salty

For high value smoked fish ….

- ☐ Do not make the Aw too low (lower than 0.83) to maintain <u>softness of the product</u> and <u>not to be too salty</u>

How to control the Aw of the smoked fish product ?



✓ Aw of the smoked fish product can be controlled (1) by steaming and (2)by adjusting the ingredients of the seasoning mixture used, and (3)marinating time of the product with the seasoning mixture, and (4) by adjusting the drying process of the product (in terms of drying time and temperature)

- Aw of the fish can be controlled by Na ion (soy source & salt) and sugar content (including honey).
  ⇒ The stronger the taste, the lower the Aw.
- Moisture content of the product can be controlled by drying and hot smoking.
  ⇒ The more dry, the lower Aw.

For higher value added smoked fish ….
Lower Aw is important for preservative quality of food. However, If the Aw is too low, it tastes too salty and/or become harder.

Lecture 4-2

PREVENTION OF FAT OXIDATION IN THE DISTRIBUTION PROCESS

Use of high barrier film to prevent the product from oxidation

In order to prevent the product from oxidation in the process of storage and distribution, use **high barrier film** (for example, **KON**) **with vacuum sealing.**

Oxygen transmission rates of some films at 25℃	
KON	10cc/m²/day
ON	80cc/m²/day
OPP	2000cc/m²/day

Recommended level of oxygen transmission rate

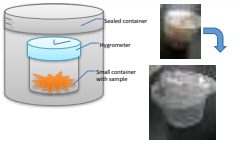
Lecture 4-3

EQUIPMENT

Measurement instrument

Aw meter

Aw measurement in simple way

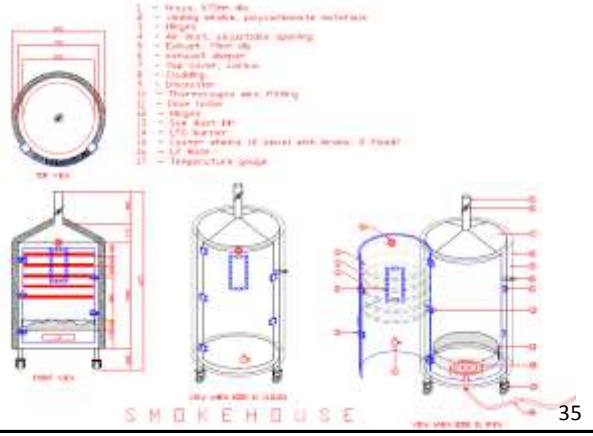


How to measure in simple way: Keep the sample and small digital or analog hygrometer in the glass bottle Or plastic container and keep several hours. (depending on the sample size)After that read the equilibrated relative humidity and temperature by hygrometer inside the bottle. Aw of the sample will be obtained from the equilibrated relative humidity (divided by 100).

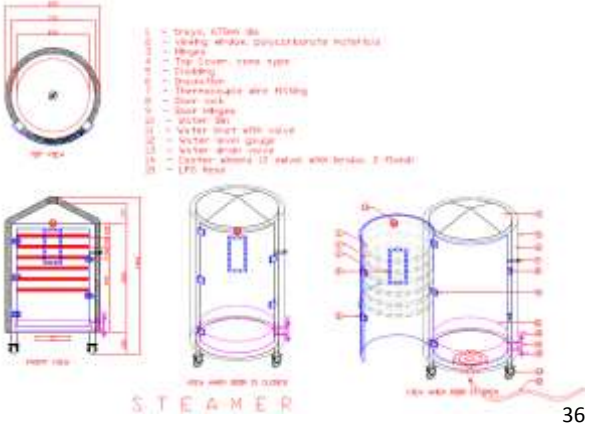
Moisture Analyzer

Thermocouples

Design drawing of Smoker



Design drawing of Steamer



Lecture 5

REDUCTION OF MECHANICAL DAMAGE DURING DISTRIBUTION OF SMOKED FISH

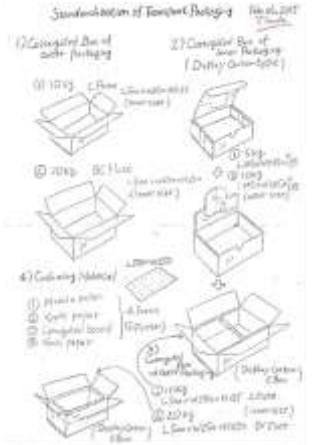
Issues focused:

Significant mechanical damage on the smoked fish during transportation because of over-stuffing the products in the transport packages (corrugated boxes)

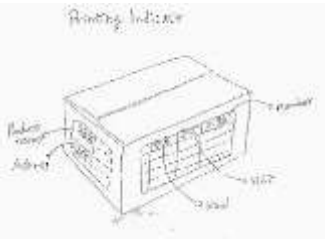
Proposed suggestion:

- Promotion of use of transport package of standard volume to prevent over-stuffing (such as 10kgs and 20kgs, etc.)

Output of the packaging (Drawing)



- **Quantity: Provision of transport package for standard volumes, such as 10kgs and 20kgs, etc.**



Lecture 6

SUGGESTION FOR POSSIBLE IMPROVEMENT OF THE PRODUCT FOR BETTER MARKETABILITY AND COMPETITIVENESS

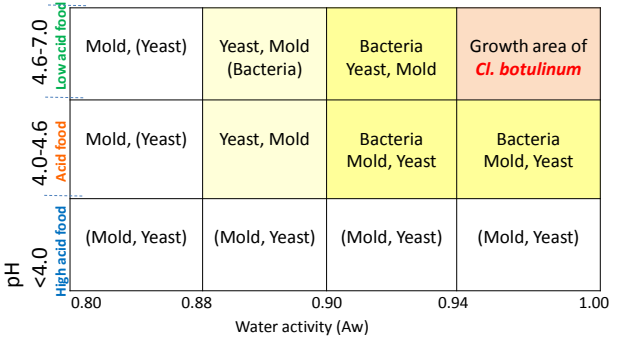
Suggestion for possible improvement of marketability differentiating your product from that of competitors

Factors	Suggestion on possible way of improvement
Smell	Use of selected wood chips good for better smell.
Flavor	Use of herbs and/or spices: the product can have different flavor from the current one.
Color	Use of light color soy sauce: Not too dark color or light color will make the product more attractive.
Softness	Avoid too much heating and too much drying. Use of enzymes of papaya and/or pineapple.
Saltiness	Adjust the balance of salt & sugar contents in the seasoning mixture: You can reduce the saltiness for good taste and for good health.
Graphic design of package	Improve the graphic design of package and label: Appealing the feature of your products with branding. Support from PTD is available.

Expand your business with High Valued Product

REFERENCES

Growth area of bacteria, mold and yeast in terms of Aw and pH



Note: ( ) means "Slow growth"

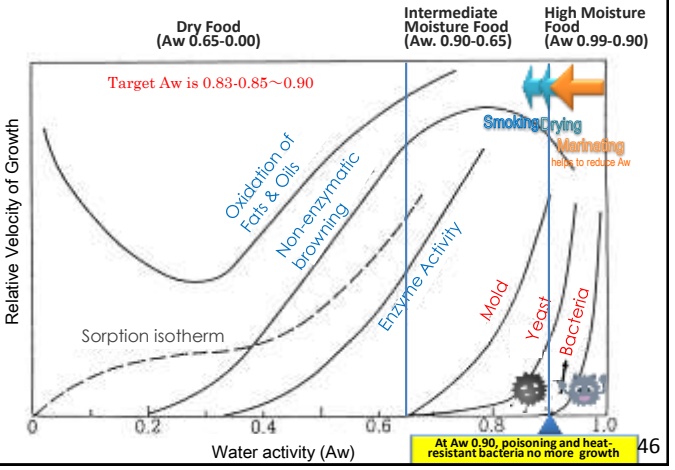
Reference(1)- How to control Poisoning Bacteria

① 1) Heat resistant spore-forming bacteria cannot grow below **0.90** of Aw
② 2) The other non-spore forming bacteria can be killed by heat pasteurization

	Bacteria	Heat treatment	Limit of Aw MHLW	Limit of Aw FDA	Infection Level /g(*)
Spore forming	*Bacillus cereus* (aerobic)	Heat resistant up to 120℃ 4mins!	0.93	0.92	100,000<
	Clostridium perfringens (strict anaerobic)		0.93	0.93	100,000<
	Clostridium botulinum Proteolytic (strict anaerobic)		0.94	0.935	100,000<
	Clostridium botulinum Non-proteolytic (strict anaerobic)		0.97	0.97	100,000<
Non-spore forming	*Staphylococcus aureus*	Usually killed at 80℃, short time No growth at 60℃, 10 min.	0.86	0.83	100,000<
	Listeria monocytogenes		0.90	0.92	?
	Vibrio parahaemolyticus		0.94	0.94	10,000<
	Salmonella		0.94	0.94	100-1,000
	enterohemorrhagic *Escherichia coli*		0.95	0.95	100>
	Campylobacter jejuni		0.98	0.98	100>

MHLW: Ministry of Health, Labor and Welfare in Japan
FDA: Food and Drug Administration in USA

Reference(2)- Relation between Aw and Microbial Growth

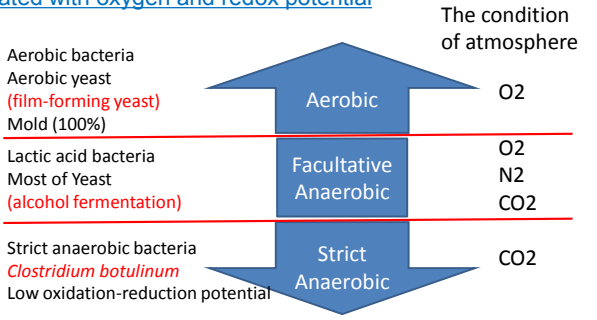


Reference(3)- Poisoning bacteria

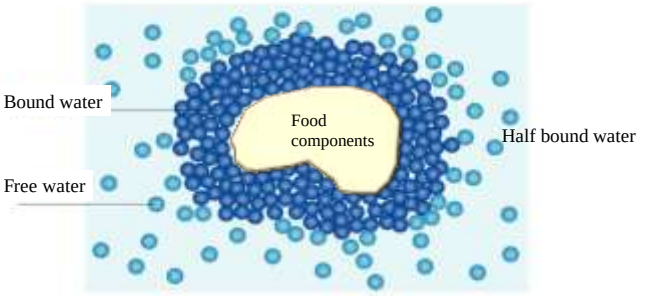
Poisoning bacteria cannot grow below Aw 0.90 except *St. aureus.*
Cl. Botulinum cannot grow below Aw 0.94
Cl. Botulinum cannot grow below pH4.6
Cl. Botulinum cannot grow under aerobic condition.
(in transparent flexible pouch)
Poisoning by *Cl. Botulinum* occur under strict anaerobic condition in bottled or canned products, or in case of blocked products of non pasteurized.
Non spore-forming bacteria can be killed by heat pasteurization of 80C, 30 min.
Spore-forming bacteria cannot be killed by only general heat pasteurization.
In this case HTST or UHT sterilization (retort) or Aw-control are necessary.

Most aerobic yeasts cannot grow below Aw 0.87, except halophilic yeasts.
There is no toxic yeast, but pouch swelling and/or off-odor development occur by yeast fermentation in the pouch.
Mold growth can be seen on the surface of products, because the molds are 100% aerobic. But some molds produce mycotoxin.
The molds and yeasts can be killed by heat pasteurization of 80C, 30 min.
Oxygen absorber should be applied for Aw-controlled foods below Aw 0.87 otherwise pouch swelling or anaerobic bacterial growth could be occur.

Reference(4)- Kinds of microorganisms related with oxygen and redox potential



Reference(5)- "Free water" content of food (Water activity : Aw)



		occurrence	high temp.	low temp.	microorganism
Water	Free water	75-85%	easy	easy	can use
	Bound water	15-25%	difficult	difficult	cannot use

Reference(6)- "Free Water" of foods (Water Activity :Aw)

- **Water activity (Aw)** is the barometer of free water content, indicated by the partial pressure of water vapor of a food divided by the standard state partial vapor pressure of pure water.
- The standard state is defined as the partial vapor pressure of pure water at the same temperature. So, pure distilled water has the water activity (Aw) of 1.00.
- **When the equilibrium relative humidity of food is RH70%**
  ⇒ Aw is 0.70 So Aw can be measured by hygrometer
- Bacteria usually require Aw of more than 0.90
  Aerobic yeast usually require Aw of more than 0.88
  Mold usually require Aw of more than 0.80
  However halophilic bacteria, osmophilic yeast and mold exist
- Water migrates from areas of high Aw to areas of low Aw.
- For example, if honey (Aw≈0.60) is exposed to humid air (Aw≈0.7), the honey absorbs moisture from the air.
- If salami (Aw≈0.87) is exposed to dry air (Aw≈0.50), the salami dries out, which could preserve it longer.

Reference(7)- Relation between Aw and Salt/Sugar

Water activity	Salt content (MW58.4) Na+, Cl-	Sugar content (*) (MW342) C12H22O11
0.995	0.872%	8.51%
0.990	1.72%	15.4%
0.980	3.43%	26.1%
0.940	9.38%	48.2%
0.900	14.2%	58.4%
0.850	19.1%	67.2%
0.800	23.1%	

Almost saturation point (26.4%)

(*)
- Glucose
- Dextrose syrup
- Isomerized glucose syrup
- Sugar alcohol (Sorbitol, etc.)
- Glycerin
- Glycine, etc.

- ✓ The higher concentration of salt/sugar, the lower Aw.
- ✓ But If you want to achieve Aw 9.0 by salt only, you should put 14.2%, which is too salty. In case of sugar only, you should put 58.4%, which is too sweet.
- ✓ So, please adjust proportion of salt and sugar to reach 8.5 with still good taste.

Good luck!!

Contact:
The Packaging Technology Division
DOST Compound
General Santos Avenue
Bicutan, Taguig City 1631
Philippines

Telephone no.: (632) 837.2071 loc. 2271
Telefax: (632) 837.7530
Email: packaging@itdi.dost.gov.ph

2.3 甘藷

Packaging Technology Development Project
for Fresh and Semi-processed Agricultural Products in the Philippines

Improved Postharvest Treatment with Use of Packaging

Sweet Potato

Packaging Technology Division (PTD)
Industrial Technology Development Institute (ITDI)
Department of Science and Technology (DOST)
With technical cooperation of
Japan International Cooperation Agency (JICA)

1 Issues of current practice and needs for improvement

Harvesting sweet potato in Tarlac city.
The temperature was going up to 38 C in the sweet potato field. (April 17th 2013)

Sweet potato field in Tarlac. The soil is very hard.
Ordinal instruments cannot be used.
Water buffalo help us for harvesting sweet potato.

Cuts, bruises or other damages caused by improper harvesting & handling were observed on the sweet potato sold in S&M market, Manila

5

Severly damaged sweet potatoes were soled in S&M market.
Beautiful appearance may give higher evaluation as the price or not ?

6

2 Suggestions for improvement

7

1. Improvement of harvesting & transporting method to mitigate mechanical damages.

Mechanically damaged sweet potato gives not only bad appearance but also the cause of higher respiration rate and thus sugars are consumed during storage and distribution.
Mechanical damaged should be prevented by proper handling and distribution.

(1) During harvesting
(2) During packaging (Bags & sacks) in the field
(3) During transporting by trucks and during handling in the market.

8

☛ Use of sack for transportation is the major factor of cause of bruises, and brushing increases the bruises further.

If crate is used for transportation, the cause of bruises can be decreased even with use of brush in washing

Package used		Classification after washing (in % of total)		
At the time of harvesting	For transportation	Class 1	Classes 1 +2	Classes 1+2+3
Current practice	Sack	0%	3.0%	100%
Crate	Sack	0%	4.2%	100%
Crate	Crate	28.3%	100%	100%
Crate (w/careful handling)	Crate	60.4%	100%	100%

Plastic containers are used for harvesting and transporting sweet potato in Japan

Steamed and packaged product

2. Curing under ambient for short period (1 week)

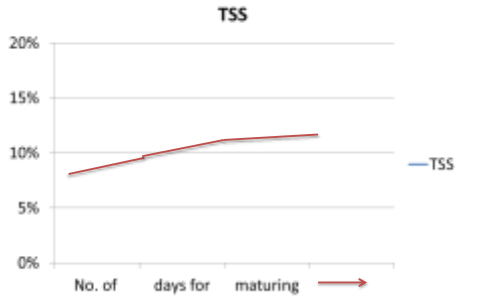
When the handling has been good in the field, the curing process is not so important in the Philippines, but the handling has been bad, curing is very important for repairing damages before maturation storage.

3. Maturation storage by controlled temperature at 13-15℃.

The sugar contents is gradually increase during low temperature storage, but storage temperature is higher than 16℃, sprouting occur in general. Shipment control of value-added products become possible.

According to the initial findings by the experiments conducted by Packaging Technology Division of DOST:

Sweetness increases with maturing.

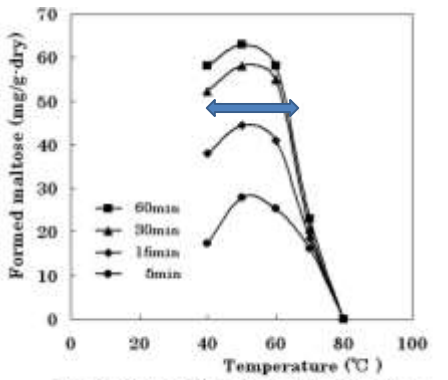


Maturation process in the warehouse of well-controlled temperature & humidity

Sweet potato is stored for 2-3 months for maturation. Sweet potato accumulates sugars during storage and become very sweet sweet potato.

4. Developing baked or steamed sweet potato product

Sweet potato contains enzyme(amylase) and activate by the temperature at 50-70℃, so keep this temperature for 40-60min., then starch is hydrolyzed and sweet maltose is produced. Branding is very important for sweetened products.



The effects of temperature and reaction time on maltose formation by sweet potato βamylase

Demand for sweet potato

Current and potential demand:	% of total demand (in the case of Japan, 2006)
As a fresh root vegetable	38%
Processed for various kinds of sweets	9%
As raw material for starch production	27%
For distilled spirit	21%
Animal feed	1%

3 Proposed Packaging/ Post-harvest Treatment for value adding

Proposal 1: Sweet sweet potato of lovely skin

Proposal 2: Adjustment of shipping timing with low temperature storage

Proposal 3: Increase in yield of sweat potato processed for export

Proposal 1:
Sweet sweet potato of lovely skin "Moncada Sweet"

- **Issues and needs for improvement**

1. More than 45% of sweet potato harvested are sold for animal feed at low prices, because of insect damages and/or mechanical damages during harvesting process
2. Sweet potato other than the above are also low in value due to poor sweetness and unattractive appearance with many bruises on the surface

Sweet sweet potato of lovely skin

- **Proposed Packaging/ Post-harvest Treatment for value adding**

1. Improvement of handling/transporting method of sweet potato
   - Do not throw sweet potato when harvesting
   - Use of crate at harvesting
   - Use of crate in replacement of sack for storage & transport
2. Application of curing process for decreasing bruises
3. Application of maturing process for increased sweetness

(Cont'd)

Sweet sweet potato of lovely skin

- **Proposed Packaging/ Post-harvest Treatment for value adding**

4. Regional-brand development for the improved product: **"Moncada Sweet"**
5. Use of corrugated box for transportation and display at retail shops as a tool for promoting the regional brand

Proposal 2:
Adjustment of shipping timing with low temperature storage

Issues and needs for improvement

- Significant price decrease due to over concentration of shipping in season

Adjustment of shipping timing with low temperature storage

Proposed Packaging/ Post-harvest Treatment for value adding

- Storage in warehouse at the production site at low temperature

  ➲Low temperature of 13℃ makes long-term storage of sweet potato possible

Proposal 3:
Increase in yield of sweat potato processed for export

Issues and needs for improvement

- Low yield rate of less than 55% of sweet potato processed for export due to high damage rate which was caused by:
  - Insect
  - Harvest practice (use of harrow, and throwing at harvest)
  - Use of sack for transportation

- **Proposed Packaging/ Post-harvest Treatment for value adding**

1. Improvement of handling/transporting method of sweet potato
   - Do not throw sweet potato when harvesting
   - Use of crate at harvesting
   - Use of crate in replacement of sack for storage & transport
2. Application of curing process for decreasing bruises

- **Note: According to the observation,**

Cause of damage	% of total harvested
Mechanical	21%
Insect	9%
Small size (feed grade)	12%
Total to be rejected	42%

➲**There is also a need for improvement of soil conditions, to be able to harvest without using harrow**