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ENVIRONMENTAL CONDITION DURING AIR SHIPMENT OF HORTICULTURAL PRODUCTS FROM OKINAWA TO TOKYO

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ABSTRACT

Air shipment affords the quickest possible delivery of horticultural products. The price of air shipped horticultural products are relatively high as most of these products are perishable. Usually the temperature in the cargo compartment is not controlled during flight. Thus, special attention should be paid to precooling prior to shipment. The environmental condition during transportation of horticultural products is an essential parameter for maintaining the quality of perishable products. Commonly horticultural products were loaded by ULD(Unit Load Devices) as a container or pallet in the aircraft (except for small aircraft). Therefore, inside temperature of the container and cargo compartment came into question. Scarce literature on the relationship between environmental condition and quality changes of horticultural products during air shipment can be found. By the stand point of keeping fresh quality, investigations on the actual condition of air shipments were carried out to improve the technique during the distribution process of fresh horticultural products. Temperature, humidity, atmospheric pressure, carbon dioxide, ethylene, impacts, and changes in quality during the air shipment of snapbeans, okras and chrysanthemums were measured. Temperature was measured by recording thermometers, relative humidity by recording hygrometers, atmospheric pressure by a strain-guage type pressure sensor, carbon dioxide by testing tubes, ethylene by sampling bags and a gaschromatograph, impacts and vibrations by impact recorders and a 3D accelerometer. Relationships between environmental conditions and quality changes during air shipments were clarified. It was expected from investigations into actual shipments that the ventilation and insulation properties of air freight containers were related to the quality of agricultural products. Aircraft can not directly load and unload trucks into them. The transshipment is inclined to cause shocks and vibrations, and to invite damages within a short time.

Key Word: Environmental condition, Air shipment, Horticultural product

INTRODUCTION

Okinawa has many beautiful maritime resorts and many sightseers visit in the summer from mainland Japan, but there is a shortage in the production of leafy vegetables in the summer due to the hot climate. Airlines introduced fresh vegetables, fruits, and fish which were in shortage, by air shipment from mainland Japan to Okinawa in the summer of 1975. Air shipment of perishable products has been becoming more popular year by year in Okinawa. In the calm winter climate of Okinawa, the yield of vegetables and cut flowers is high. Vegetables and cut flowers began to be transported from Okinawa to mainland in winter and spring by air freight after the introduction of the Boeing 747. Freight traffic has been increasing yearly. The freight traffic was larger than the capacity of the scheduled air freight from Okinawa to mainland Japan during peak season by the end of the 1970s. In 1984, the chartered air freighter was realized and began to carry cut chrysanthemums for Buddhist ceremonies in the spring equinox. Afterwards, the number of chartered air freighters has been increasing year by year as indicated in Table 1.

Table 1. Amount of cut flowers shipped by chartered air freighters

Fiscal year	Aircraft	Weight(t)
1984	DC8Fx3	75
1985	B747Fx2+DC8Fx3	273
1986	B747Fx4+DC8Fx1	328
1987	B747Fx3+DC8Fx3	308
1988	B747Fx6	444
1989	B747Fx7	557
1990	B747Fx9	698
1991	B747Fx9	650
1992	B747Fx9	724
1993	B747Fx9	760

MATERIALS AND METHODS

A knowledge of environmental conditions during shipments should constitute important and essential engineering data to keep fresh quality of horticultural products. Environmental conditions during railway and truck shipments were reported on strawberries "Chuma(1970)", Satsuma mandarins "Chuma(1972)", lettuces "Iwamoto(1978)" and many other examples. In the case of

Table 2 Environmental conditions and their measuring instrument

Factor	Instrument	Date	Flight	Material
Temperature	Yoshida	26 Jan. 1981	JL906	Snapbeans
	model RT 101H	11 June 1981	JL906	Okras
	thermorecorder	16 Mar. 1986	JL2936	Flowers
		15 Mar. 1992	YU6994	Flowers
Relative	Sato	11 June 1981	JL906	Okras
humidity	model 7008/NS2	16 Mar. 1986	JL2936	Flowers
	thermo hygrorecorder	15 Mar. 1992	YU6994	Flowers
	Shimadzu	24 Feb. 1982	JL906	Snapbeans
	model 2577			
	thermo hygrometer			
Pressure	Toyo Boldwin	30 Jan. 1980	JL906	Snapbeans
	model GDB-2			
Impact	Yoshida	29 Nov. 1977	JL920	Pines.
	model FIR-102	4 Mar. 1982	JL902	Snapbeans
	model FIR-301	23 Mar. 1982	JL902	Flowers
	impact recorder			
	Shinkoh			
	model BA-10LT			
	3D accelerometer			
Carbon	Gastec	18 Mar. 1989	JL1936	Flowers
dioxide	test tube	15 Mar. 1992	YU6994	Flowers
Ethylene	Sample bag			
	Shimadzu Gaschro			
	model GC-7A FID	15 Mar. 1992	YU6994	Flowers

sea shipment, many experimental reports were published. There are some literatures on the temperature conditions during air shipment of precooled strawberries in the USA "Harvey (1976)" and South Africa "Truter (1975)". These contain very little information on the relationship between quality changes and environmental conditions. Precooling had not been sufficiently developed in Okinawa. At that time, most horticultural products were shipped by air without temperature maintenance from Okinawa. Environmental conditions during air shipments were measured as Table 2.

Temperature and relative humidity

Temperatures during air shipments were measured by Yoshida model RT101H clock driven recording thermometers or by Sato model 7008 and NS2 clock driven thermo hygrorecorders, or a Yokogawa

model 2577 hygrothermometer and a Yokogawa model 3057 recorder. The general purpose air freight container has no heat insulation function as it is made from light alloy. High temperatures inside the containers were expected. Therefore, the measurement of temperatures inside freight containers were carried out to inspect the heat insulation of the container.Temperatures inside air freight containers were measured by a Chino model DR 56A degital detalogger and type T thermocouples.

Atmospheric pressure

Atmospheric pressure during air shipment was measured by a Toyo Boldwin model DGB-2 pressure sensor, a Sinkoh model 6008 strain amplifier and a TEAC model R-81 data recorder.

Impacts and vibrations

Impacts and vibrations during air shipment were measured by three Yoshida model FIR-102 impact recorders, a Yoshida model FIR-301 3D impact recorder, and a Shinkoh model BA-10LT 3D linear accelerometer, a Shinkoh model 6008 strain amplifier and a TEAC model R-81 data recorder.

Carbon dioxide concentration

Carbon dioxide concentration in the cargo compartment of the B747 freighter during the chrysanthemum shipments from Naha to Narita and Naha to Nagoya were measured by gas samplers and test tubes. 4mm in inner diameter Tygon tubes were used for gas sampling. Gas sampling points were set up in the cockpit, in the cargo compartment, and in a container. Measurement were taken at 20 min increments after take off.

Ethylene concentration

Ethylene gas in the cargo compartment of the B747 freighter during the chrysanthemum shipments from Naha to Nagoya were sampled by a Shibata model MP-2N portable air sampler and plastic gas sampling bags. Sampling points were the same for carbon dioxide. Sample bags were brought back to the laboratory. Ethylene gas concentrations were measured by a Shimadzu model GC-7A gaschromatograph with a FID detector, a Shimadzu model FLS-3 fresh sampler, and a Shimadzu model C-R6A chromat pack data processer.

RESULTS AND DISCUSSION

Temperature and relative humidity

The inside temperature of a light alloy-made air freight container easily increases under the direct sunlight at the airfield as illustrated in Fig. 1 . Temperatures just below the ceiling reached 45 C. Such temperatures are adverse the

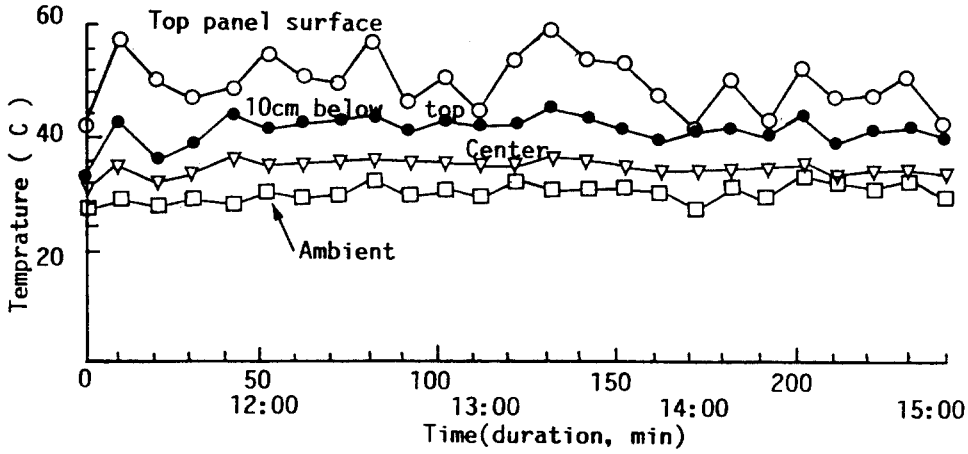

Fig.1 Changes in inside temperatures of DVN type air freight container at Naha airport on May 15, 1986

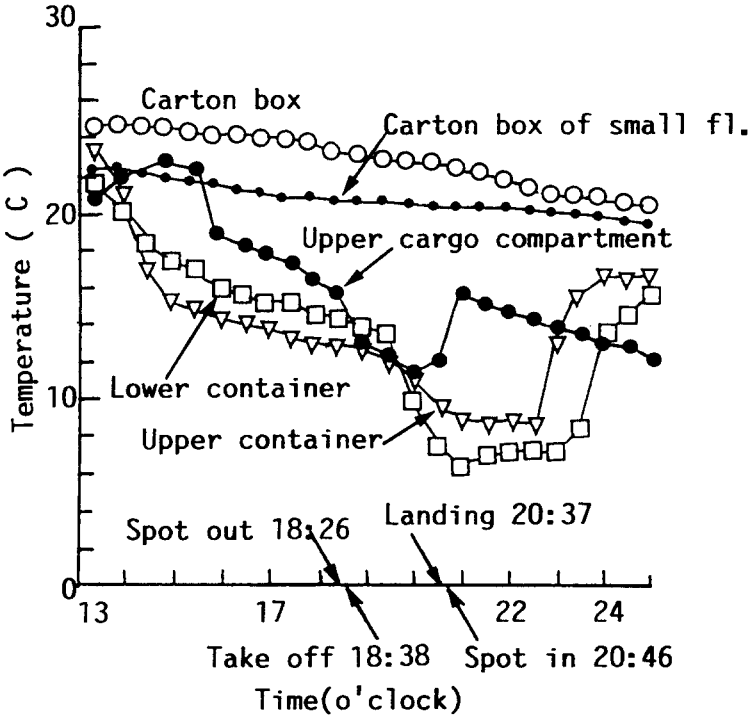

Fig.2 Changes in temperatures of cut chrysanthemum flowers during transportation by B747 freighter from Naha to Narita by JAL 2936 on March 16, 1986

freshness of horticultural products. Changes in temperature of chrysanthemum cut flowers during air shipment by a chartered air freighter(B747F) from Okinawa to Narita is illustrated in Fig.2. In this case, temperatures in the cargo compartments were controlled. The refrigerated cargo compartment was able to prevent the temperature rising with the influence of respiration. Most aircrafts have pressurized cabins and are air conditioned, except small nonpressurized aircrafts. The humidity in the cockpit and cargo compartment are kept very low at 20 to 40%R.H. as shown in Fig.2. However the relative humidity in the freight container loaded with Okra without precooling was raised by the respiration of the Okra and transpiration during the flight as a function of times is shown in Fig.3 "Akinaga(1987)". The differences between the humidity in the cargo compartment and inside container were considered to be a result of poor ventilation characteristics of the air freight container.

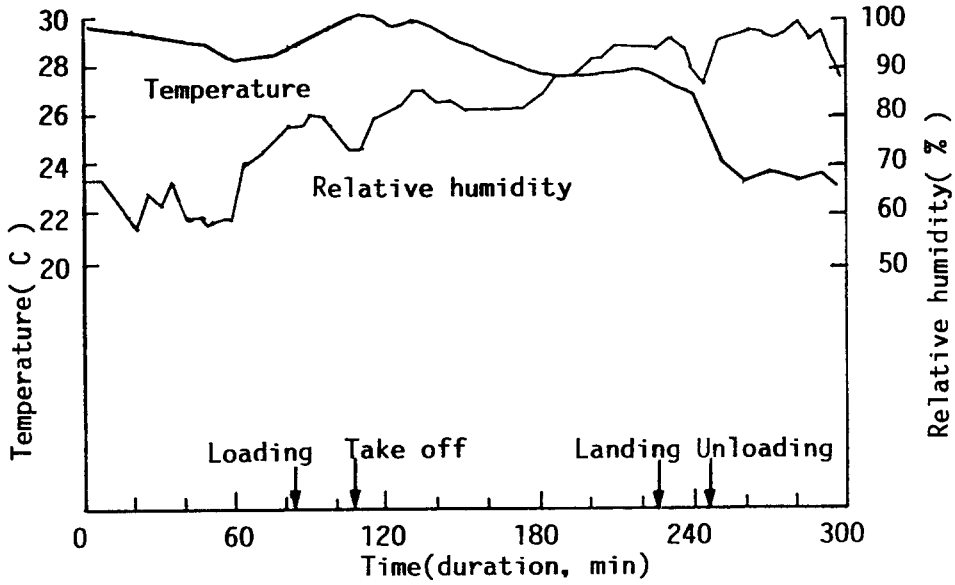

Fig.3 Changes in temperature and relative humidity inside container loaded Okras during transportation from Naha to Haneda by JAL906 on June 11, 1981

Atmospheric pressure

Atmospheric pressure of the passenger cabin in aircraft at about 7,500m in altitude is regulated to be near ground pressure and at over 12,000m is regulated to the atmospheric pressure at 2,000m in altitude. A typical change in atmospheric pressure during flight is illustrated in Fig. 4 " Akinaga et al (1981)". Research by USDA and Lockheed indicated that injury from the lower atmospheric pressure was not so severe, except for sudden pressure drop "Claypool et al(1958)".

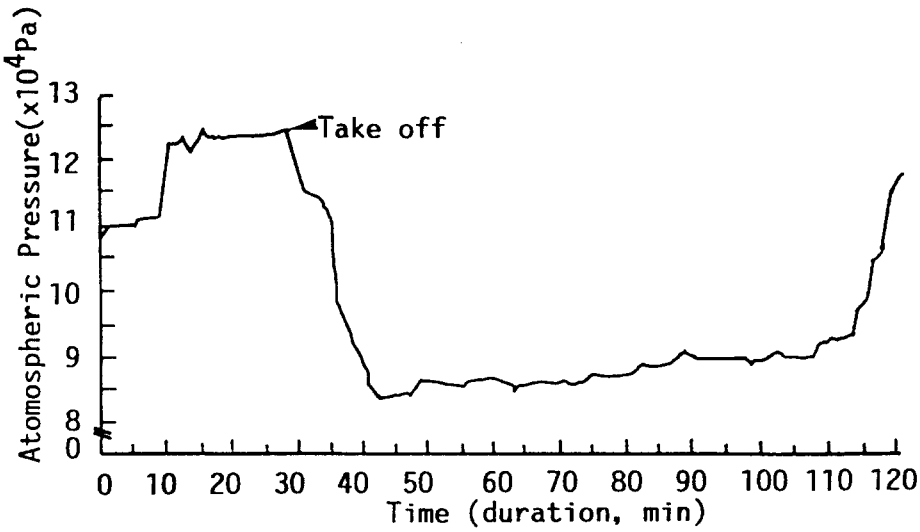

Fig.4 Changes in atmospheric pressure in the container during the transportation by JAL 906 on January 30, 1980

Table 3. Frequency of the impacts in vertical direction during the air shipment of pineapple fruits

Stage/number of impact / magnitude in G	0.5-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0- *
Univ. to Naha airport	24	2	2	2	
Transshipment & loading	7	2	1	-	
Take off Naha	2	-	-	-	
in flight	-	-	-	-	
Landing Fukuoka	3	1	-	-	
Unloading	5	3	2	-	
Loading	11	1	2	4	
Take off Fukuoka	-	-	-	-	
in flight	-	-	-	-	
Landing Naha	1	-	-	-	
Unloading	13	5	-	4	
Naha AP to Univ.	9	3	-	-	

* scale over, not measured

Impacts and vibrations

Frequency and magnitude of impacts and vibrations are varied due to the transportation system, and injury of the horticultural products during the shipments are varied due to their own bearing capacities of impacts and vibrations. Aircraft can not directly

load trucks into them or unload trucks from them. The transshipment is inclined to cause impacts and vibrations, inviting damage in a short time. Table 3 indicates the frequency of impact in the vertical direction during the air shipment of pineapple fruit from Okinawa to Fukuoka by DC8-61"Akinaga(1978)". When freight containers were loaded and conveyed into aircraft by manual operation, the damage was caused by rough handling during loading or unloading. Frequency and magnitude of impacts during air shipment using medium size passenger aircraft such as B737, MD87 etc., which have only bulk cargo compartments, are greater than that using aircraft which have container cargo compartments.

Carbon dioxide concentration

Carbon dioxide concentrations that are too high have some adverse effects on the physiological properties of cut flowers. Changes in carbon dioxide concentration during the air shipment of chrysanthemum cut flowers from Okinawa to Nagoya by B747 freighter is illustrated Fig.5. Carbon dioxide was measured at not greater than 800ppm in the cargo compartment. However, carbon dioxide inside the ULD which was packaged using PVC film for waterproofing temporarily reached about 5000ppm. It might be considered that these levels of carbon dioxide have no effect on the quality of chrysanthemum.

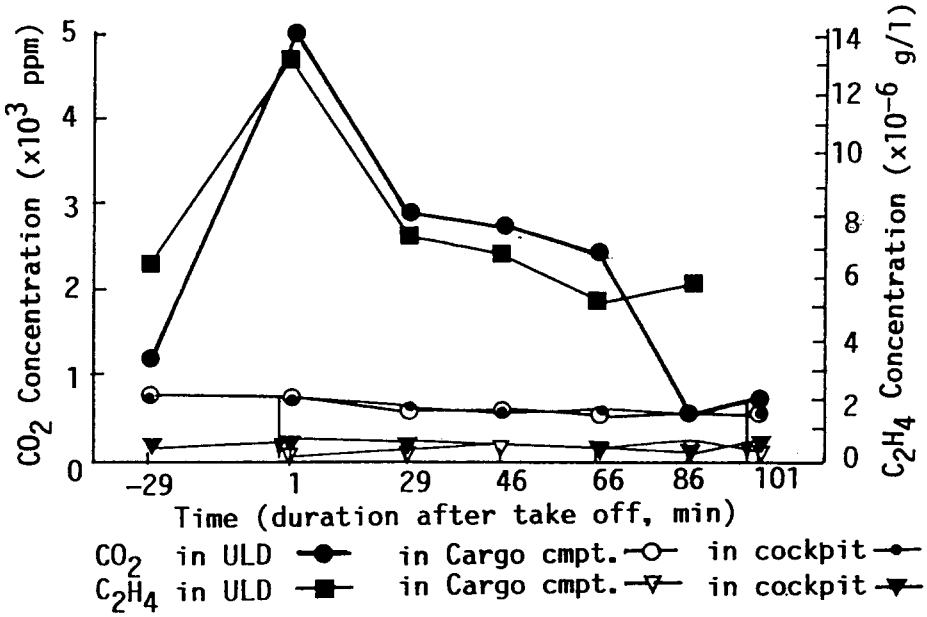

Fig.5 Changes in carbon dioxide and ethylene concentration during the air shipment of chrysanthemums from Naha to Nagoya by YU6994 on March 23, 1992

Ethylene concentration

Ethylene commonly stimulates senescence in green tissues. The sescence of some flowers is stimulated by ethylene at very low concentration "Reid (1992)". Ethylene concentration during the air shipment of chrysanthemum cut flowers is illustrated Fig. 5. Ethylene concentration in the ULD reached 13.1×10^{-6} g/l (0.23ppm). Since the measurements reported are for atmospheric composition only, influence of ethylene on the quality of chrysanthemums cannot be determined. Further studies on the effect of ethylene concentration and exposed time on the quality of chrysanthemum cut flowers are required.

CONCLUSION

Problems concerning the air shipment of Okinawan grown horticultural products were analyzed and the fundamental environmental conditions such as temperature, relative humidity, atmospheric pressure, carbon dioxide, and ethylene during air shipment were clarified.

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