FINAL REPORT

Covering period February 1996 to November 1999

Submitted to the Office of the Science Advisor
U S Agency for International Development

Self Regulated Atmospheres to Prevent Fungal Damage in Moist Paddy

Principal Investigator Ezra (Jonathan) Donahaye
Grantee Institution Agricultural Research Organization
(Volcani Center) Israel

Collaborator Silvestre C Andales
Bureau of Postharvest Research and Extension
(formerly NAPHIRE)
Philippines

Project Number C12-057

Grant Number TA-MOU-94-C12-057

USAID Program Coordinator Dr Judith Chambers

Project Duration 27th January 1995 - 30th November 1999

PROJECT STAFF

Israel

Jonathan Donahaye - Principal Investigator

Shlomo Navarro - Co Investigator

Nachman Paster - Co investigator

Miriam Rindner - Technical Staff

Avi Azrieli - Technical Staff

Mazal Menasherov - Technical Staff

David Chernoguz - Technical Staff

Rafael Dias - Technical Staff

Philippines

Sivestre C Andales Principal Co-Investigator

Filipinas M Caliboso- Co-Investigator

Glory C Sabio - Research Officer

Gemma Mallo - Technical Staff

Don David Julian - Technical Staff

Emelie C Ablaza - Technical Staff

Joel V Dator - Technical Staff

A

Table of Contents

Page number

3 Executive Summary 1
4 Research Objectives 3
5 Methods and Results 5
5 1 Laboratory studies on factors affecting grain conservation under gas tight conditions (Israel) 5
5 1 1 Metabolic activity 5
5 1 2 Effect of gas tight conditions on fungal contamination 7
5 1 3 germination 8
5 2 Laboratory studies on factors affecting paddy under gas-tight conditions (Philippines) 9
5 2 1 Methodology 9
5 2 2 Results and discussion 11
i) Physical parameters 11
ii) Grain quality parameters 12
5 3 Pilot scale studies on factors affecting grain conservation under gas tight conditions 14
5 3 1 Permeability of liners to gases 14
5 3 2 Field trial with moistened wheat 14
5 4 Reflective covers (Israel and Philippines) 15
5 4 1 Introduction 15
5 4 2 Methodology and Results (Israel) 15
5 4 3 Methodology and Results (Philippines) 17
5 5 Field Trials Philippines 19
5 5 1 Materials and methods 19
5 5 2 Results and discussion 21
5 5 2 1 Physical parameters 21
5 5 2 2 Grain quality parameters 23
5 6 Summary and Conclusion 26
6 Impact Relevance and Technology Transfer 27
7 Project Activities/Outputs 28
8 Project Productivity 28
9 Future Work 28
10 Literature Cited 29

Appendix 1 Donahaye J E Chernoguz D Navarro S Azrieli A Rindner M and Andales S C (1998) Respiration rates of paddy at different temperatures and moisture contents Proc 18th ASEAN seminar on Grains Postharvest Technology March 11-13 1997 Manila Philippines pp 145 152

Appendix 2 Angelita M del Mundo and Angelina dR Felix (1998) Sensory qualities of milled raw and cooked rices from a paddy stored with different moisture contents and under various storage durations Final Contract Report Institute of Human nutrition & Food UPLB Laguna Philippines 17 pp

Appendix 3 Angelita M del Mundo and Angelina dR Felix (1998) Sensory qualities of milled raw and cooked rices from wet paddy stored in a Volcani cube Final Contract Report Institute of Human nutrition & Food UPLB Laguna Philippines 26 pp

Appendix 4 Donahaye J E Navarro S Filipinas Caliboso Glory Sabio Gemma Mallo and Dator J (1999) Prevention of moisture migration in sealed stacks stored in the open in the tropics using reflective covers 19th ASEAN Seminar on Postharvest Technology Ho Chi Min City Vietnam 9-12 Nov 1999 (accepted)

3 **Executive Summary**

The objective of this project was to provide a solution to the acute problem in far eastern Asia where paddy rice is harvested at high moisture contents (MCs) during the monsoon season This paddy must then be dried rapidly to a safe MC in order to prevent it from molding and rotting However if the paddy is dried rapidly from about 30% to the required safe MC the grains suffer stress resulting in cracking and breakage To overcome this problem a two stage drying procedure has been advocated where the paddy is initially dried to 18% (intermediate MC) at which stage yeast and bacterial activity are suppressed followed by a second stage drying from 18 to 14% MC to prevent the development of storage molds However the drying problem is compounded by the fact that most farmers do not have flash dryers and are obliged to sell their grain directly to the traders Even if flash dryers are available insufficient capacity of second stage dryers creates a bottleneck at harvest time

Our project was designed to develop a technology that would enable farmers to overcome this bottleneck at the second drying stage by providing them with a means of storing the intermediate MC paddy under tightly sealed conditions and thereby prevent spoilage for prolonged periods until drying by sun or machine is again an available option

The present policy of the Filipino government is directed at providing small scale farmer cooperatives with on site storage units so as to decentralize storage of the national grain reserve as well as provide rural communities with a higher level of food security Implementation of this policy is under way and already the concept of sealed storage to protect dry grain from insect infestation has been widely promoted together with the distribution of flexible plastic outdoor storage cubes that were developed by ARO and BPRE as the outcome of a previous CDR project (C7 053) In 1998 about 200 units of these storage structures were purchased and distributed to farmers cooperative recipients nationwide Recently the government has purchased an additional 300 units for distribution among farmer cooperatives through soft-loans This is being done as a mitigating measure in anticipation of La Niña

However the problem of harvesting moist paddy in the rainy season still remains Although both the previously developed storage technology and the present one are based on the same principle of hermetic storage the objective of the present project was to employ the principle of self-regulated atmospheres caused by aerobic metabolism in order to arrest fungal development and preserve grain quality in paddy of intermediate MC Here to prevent spoilage oxygen depletion must be much greater and more rapid than that required to control insects and it was anticipated that this would require a higher level of hermetic seal than that required for insect disinfestation

The first two questions to be answered before field trials could be initiated were - do the rates of oxygen depletion obtainable by sealed storage of moist paddy prevent mold proliferation sufficiently in the damp grain and - can hermetic storage of intermediate MC grain be carried out without having a deleterious influence on the aroma taste and cooking qualities of the rice?

Both these aspects were studied during the first and second years with laboratory studies in the Philippines being undertaken on the effect of hermetically sealed moist paddy stored for different time periods on different quality parameters including milling and organoleptic characteristics while in Israel studies with the same paddy and also wheat were directed at evaluating rates of aerobic metabolism at different moisture contents and temperatures as a basis for determining rates of oxygen depletion within the storage structures

In the first year a flexible storage structure of 10 tons capacity was manufactured from a plastic laminate chosen from a series of materials that were screened to test their permeability to oxygen and carbon dioxide This structure was field-tested prior to shipping for paddy storage trials to be undertaken in the Philippines

Although calculations indicated that the low permeability of the liner material would give a sufficient seal to reproduce laboratory conditions an additional factor was anticipated to have an influence on the storage environment under field conditions This was the development of air convection currents within the stack that carry moisture and deposit it at the top layer These currents develop when temperature gradients are formed as a result of diurnal temperature fluctuations This phenomenon was noted in the previous study when storage cubes were set-up in un shaded sites As a counter measure an insulating layer of rice hulls was placed over the top layer of bags and this solution was adopted as standard procedure However for the storage of

intermediate MC grain the situation is much more critical since any rise in MC above 18% is liable to enable the anaerobic metabolism of bacteria and yeasts that have a strong influence on grain quality particularly taste and aroma

An improved solution developed during this project was the use of an external reflective shade cover placed over the storage cube in order to reduce temperature gradients within the grain and thereby minimize the moisture migration phenomenon Initial trials that were carried out in both countries in the second year were inconclusive However after modifications further trials carried out during the third year in both countries gave positive results that have led to adoption of this concept for all outdoor storage in plastic liners and inclusion of reflective covers in the standard commercial kits

It was clearly demonstrated in the first year that the rates of oxygen depletion in hermetically sealed moist paddy could prevent mold proliferation but the effects of hermetic storage upon paddy quality took longer to evaluate than planned as this required repeat experiments to enable in-depth evaluations of cooking and acceptability parameters that were carried out by Prof Del Mundo at the University of the Philippines Los Baños after 1 3 and 6 months of storage The project findings indicated that after 1 month quality of sealed paddy stored at up to 18%MC had not deteriorated However further evaluations made on paddy stored hermetically for 1 3 and 6 months under both laboratory and field conditions confirmed that after the first month of storage the quality of moist paddy (16-18% MC) deteriorated progressively and the grain was no longer acceptable by the taste panels These findings enable the following tentative recommendations to be made for paddy storage duration

	For 18% MC	one (1) month
(not confirmed	For 17% MC	one (1) month
by	For 16% MC	can be extended to two (2) months
field trials)	For 15% MC	can be extended to three (3) months
	For 14% MC	still the recommended level for long term paddy storage

In conclusion the present widespread implementation of the hermetic storage technology at the cooperative and village level throughout the Philippines has been backed up with BPRE initiated on-the-spot extension courses Many aspects of this technology have not yet been explored especially field validation of the laboratory findings at 15 17% MC However will we anticipate that this enterprise will serve as a starting point for the adoption of hermetic storage to protect paddy of intermediate MC until it can be dried

4 Research Objectives

Rice is one of the most important food crops in the world and dependence upon its availability is a determining factor for food security of large sectors of the predominantly rural population and also the urban poor In Asia, rice is the major cereal crop, and in many countries national policy is towards self sufficiency and export This has been achieved by the development of high yielding varieties with reduced growing seasons that have enabled farmers to produce larger harvests However, the double cropping of early maturing varieties requires harvesting to take place during the monsoon season when the moist grains cannot be sun dried Most of the rice is grown by small scale farmers who possess neither storage, nor artificial drying facilities Consequently losses after harvest (before the grain can be sun-dried) due to mold development are high, or the grain has to be sold immediately to traders who have the facilities to dry it rapidly Therefore the farmer is unable to control the price of his harvested paddy at the farm-gate and is obliged to sell at the moment of glut when prices are lowest This problem of harvesting moist HYV paddy during the monsoon season has been recognized as THE major cause for losses by the small scale farmer (see FAO-IRRI/AED Rice Post-Harvest Conference summary by Dante de Padua, 20 10 97)

In the Philippines, more than half of the total annual local production of paddy-rice is harvested during the wet season (Philippine Agribusiness Fact Book and Directory, 1991-1992) Paddy is usually harvested at 20 to 21% MC during the dry season and 28 to 30% MC during the wet season (Mendoza et al, 1984) In a survey conducted by Tolentino et al (1992), the purchase of wet paddy by rice traders in Bulacan and Nueva Ecija provinces is about 53% of the total volume produced during the wet season and 13% of the total volume during the dry season This indicates the high volume of wet paddy handled during the rainy season

The use of mechanical dryers has been so far the recognized method of preventing deterioration of wet paddy during the rainy season However, the high cost of investment, maintenance and operation, are among the constraints limiting the adoption of this method especially in rural areas (Bermundo and Quiambao, 1984, Lorenzana, 1985) To this day, sun drying continues to be the most favored method of drying paddy Thus during the rainy season, farmers and traders alike are forced to wait for the sun to shine

A rapid change in the quality of paddy has been observed when drying is not carried out immediately after harvest Rice yellowing (generally attributed to heating and microorganism activity), increases significantly after two weeks and one month delays in drying of paddy with an initial MC of 23-25% and 20-22%, respectively Likewise, for paddy with an initial MC of 30%, yellowing increases significantly after 2 days delay in drying (Mendoza et al 1982) The increase in yellow kernels in milled rice creates an economic problem for producers and traders because yellow rice commands a low price in the market Mendoza and Quitco (1984) provide computations of monetary losses due to yellowing As a result of yellowing it has been estimated that up to 30% of the value of the country's total stocks is lost (Anon , 1988) Rice yellowing of moist paddy has also been investigated in Indonesia including isolation of associated fungi (Phillips et al, 1989) Other evaluations of deterioration of moist paddy under aerobic conditions were used by Matsuda et al (1974) including fat acidity and germination as qualitative indices and odor as a

qualitative index

The difficulty in adoption of mechanical dryers necessitates the examination of alternative solutions to the fungal deterioration of wet paddy The use of chemicals (such as propionic acid) in the storage of wet paddy has been found effective in inhibiting deterioration due to fungi However, this has posed some limitations due primarily to its prohibitive cost

The use of airtight conditions or modified atmospheres for preventing deterioration of high moisture paddy during temporary storage until it can be dried, offers a novel possibility for farmers to maintain quality for prolonged periods In rice, most storage fungi are inhibited by atmospheres with less than 1% O_2, (Richard-Molard et al, 1986), whereas carbon dioxide (CO_2) concentrations in air of greater than 80% may be required to prevent fungal deterioration of high moisture commodities (Hocking, 1991)

The present policy of BPRE (formerly NAPHIRE) advocates two stage drying, whereby high moisture paddy should be dried down to below 18% MC in the first stage to minimize rapid deterioration followed later by drying of intermediate moisture paddy down to 14% MC (Andales, 1987) This project therefore aimed at finding an alternative to the second stage of drying or to delay the need to undertake the second drying stage beyond the presently acceptable holding period of 21 days (Quitco 1983)

The project's hypothesis is that at MCs below the level permitting bacterial growth, namely at water activity (a_w) <0 87, most storage fungi are fully inhibited in atmospheres containing less than 1% O_2 In addition, risks of mycotoxin production are nullified at reduced O_2 concentrations (Paster, 1987, Paster and Bullerman, 1988)

However, the influence of intrinsic and extrinsic factors governing microfloral activity of moist grain, and particularly paddy, under hermetic storage, requires further clarification in order to reveal the inter-relationships in the "grain-microflora" ecosystem An important aspect of this research project which needs further elucidation, is the aerobic stability of paddy after opening the hermetic structures and prior to its utilization for human consumption (Diawara et al, 1986) This matter has not yet been clarified

The storage of grain in gastight structures is a well known method to prevent insect activity in dry grains, and has been applied in practice including storage of grain in flexible plastic enclosures (Donahaye et al, 1991, Navarro and Donahaye, 1988) Therefore it was postulated that the plastic industry is now capable of manufacturing durable, weather resistant liners to a degree of gas tightness that will restrict microfloral activity

The objective of preventing losses using the aspects of microfloral and atmospheric gas composition interactions has not yet been addressed to problems encountered in tropical countries The sparse literature on hermetic storage in the tropics has been based on the use of gastight metal structures These tends to be susceptible to the establishment of temperature fluctuations that cause moisture migration and also encourage air infiltration caused by a pumping effect through leaks due to pressure differentials Preliminary experiments using flexible liners in the tropics indicate that these problems can be significantly alleviated with encouraging results (Donahaye et al 1991, Navarro and Donahaye 1985, Navarro and Donahaye 1988)

In the light of the above rationale, the objective of this project was to develop a storage solution for paddy at moisture contents above critical levels but below a_w 0 87 (equivalent to about 18% MC), by inhibiting fungal development For this purpose, a flexible plastic structure was designed with a sufficiently tight hermetic seal that the self-generated metabolic activity of the paddy reduces oxygen concentrations to below 1% This should enable the paddy to be stored without microbial damage until mechanical dryers become available, or sun-drying can be carried out at leisure, or in countries where parboiling or steam-boiling are practiced, the paddy can be processed
The innovative aspect of this research is that it was the first attempt at providing a technologically sound alternative to two-stage drying, and at the same time providing the farmer with the means of delaying sale of his harvested grain until the price is right
Present national policies are directed towards decentralizing storage reserves by increasing storage capacity in rural areas Consequently, flexible sealed storage structures as developed in a previous CDR project (C7-053) are now being increasingly used in the Philippines at the cooperative level Therefore this storage concept dovetails with existing policy trends

5 Methods and Results

5 1 Laboratory studies on factors affecting grain conservation under gas-tight conditions (Israel)

The objective of the first laboratory studies, before field trials could be initiated, was to examine the rates of oxygen depletion obtainable by metabolic activity under sealed storage of moist paddy and then verify how these rates would affect germination, and whether they could effectively prevent mold proliferation in the damp grain

5 1.1 Metabolic activity

Respiration studies were undertaken to evaluate paddy conservation under different combinations of water activity and temperature A parallel series of experiments was carried out on wheat both for comparative purposes, and in order to provide data for preliminary field trials with experimental storage containers to be carried out in Israel, using wheat as a substitute for paddy

i) Paddy

In order to determine the potential of paddy to generate self-regulated atmospheres under completely gas-tight conditions, controlled laboratory experiments were undertaken with five target levels of MC, namely, 14, 15, 16, 17 and 18% w b approximately corresponding to the following water activities a_w 0 75, 0 80, 0 85, 0 88 & 0 90

The experiments were undertaken at 25, 30° and 35°C, for three storage durations of 1, 3, and 6 months A rice variety widely planted in the Philippines (IRRI 64) was used for the experiment Paddy that arrived from the Philippines at an initial MC of 13 06% was moistened to the desired MCs before the start of the experiment After moistening, glass jars

were filled with paddy (370 g/jar) The jars were sealed hermetically with screw type metal covers equipped with septa for gas sampling, and transferred to thermostatically maintained chambers at the desired temperatures The rates of respiratory metabolism as expressed by O_2 intake and CO_2 output were determined at regular graded intervals, by gas chromatography using a thermal conductivity detector To evaluate metabolic activity inside the sealed system, the absolute weight of O_2 consumed by the grain was calculated To do this, a manometric method using transducers was used to determine the interstitial space and headspace of the grain in the experimental jars Paddy that arrived from the Philippines was derived from the same lots as those used by BPRE for their laboratory experiments (see Section 5 2) Two sets of experiments were carried out because the first consignment of paddy was later found to consist of rain damaged grain with an initial germination level of 23% Therefore the laboratory trials in both the Philippines and Israel were repeated using high quality paddy with a germination rate of 91%

The experiment was divided into two trials The first was designed to record rates of change in gas composition under completely sealed conditions The principal findings of this trial have been published (Donahaye et al 1998) and are not reported in detail here They can be summarized as follows For good quality paddy, at all three temperatures, there was an approximate doubling (x 1 7) in respiration rate for every unit increase in MC over the range tested, and for rain damaged paddy, this ratio was slightly higher (up to x 1 9) Similarly, for every 5°C increase in temperature, the increase in respiration ranged from x 1 7 to x 2 2 for good quality paddy, and for rain damaged paddy from x 1 5 to x 1 95 A linear relationship was found between respiration rates expressed as log of oxygen consumption in mg O_2/100g/dry matter/ day plotted against paddy MC For 18% MC at 35°C, respiration rate of high quality paddy was 20 36 mg O_2/100g dry matter/day, and for 14% MC paddy at 25°C it was 0 604 mg O_2/100g dry matter/day For the same temperatures and MCs the low quality paddy gave values of 17 175 and 0 585 mg O_2/100g dry matter/day

ii) Wheat

In order to prepare for the pilot-scale field trial to be carried out in Israel, where wheat is the only conveniently available cereal grain, an identical trial was carried out using wheat moistened from an initial 9 79% MC to the same range of target MCs and held over the same range of temperatures Rates of O_2 consumption and CO_2 output at the different MCs were measured and these are given at the 35°C level in Fig 1 The calculated metabolic activity of wheat inside the sealed jars under different temperatures is given in Fig 2

The Figures show that for wheat, the rates of self-regulation of atmospheres in gas-tight jars showed a similar dependence on MC and temperature but were consistently higher than those of paddy

Fig 1 Measured rates of oxygen consumption and carbon dioxide output of wheat held at

different moisture contents in gas tight containers at 35°C

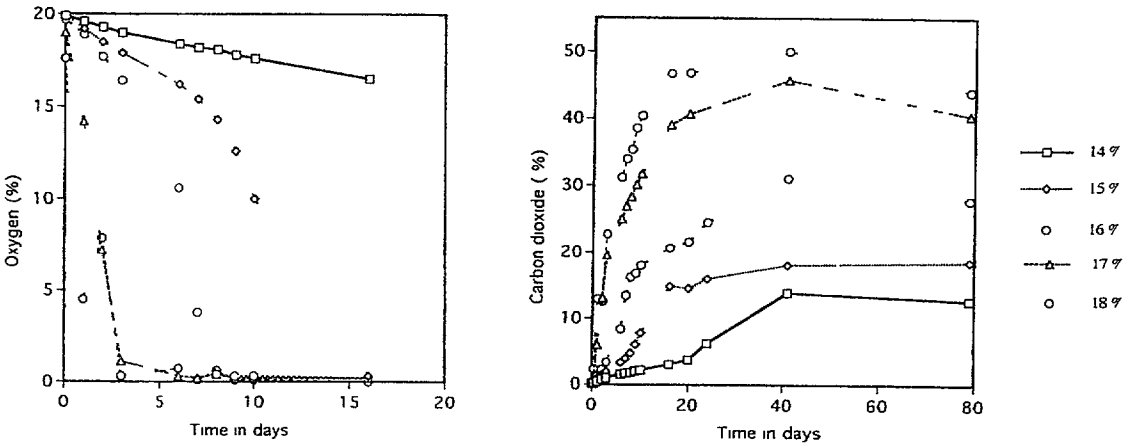
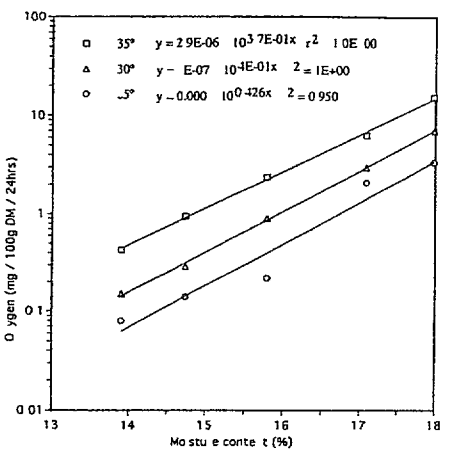


Fig 2 Effect of moisture content and temperature on the metabolic activity of wheat in a gas-tight container



5 1 2 Effect of gas-tight conditions on fungal contamination

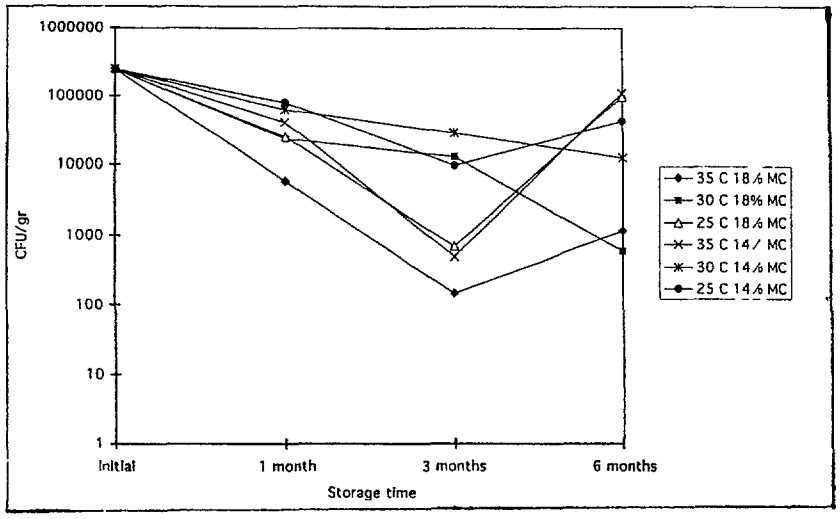
i) paddy

This trial carried out both on rain damaged paddy and good quality paddy, was designed to evaluate the influence of the atmospheres so obtained on microfloral growth Glass vials (100 ml) were filled with paddy moistened to the desired MCs Contrary to the respiration trials, gas samples were only taken directly after sealing, and a day later to verify gas-tightness Final gas samples were taken at the end of the trial, immediately prior to opening the vials for analysis of microflora Final MC determination of each sample was also measured at this stage

Fungal contamination was evaluated using a standard plating method after 0, 1, 4, and 6 months of sealed storage The data obtained on total fungi count clearly revealed that for both qualities of paddy, the fungistatic effect of the gas-tight conditions are well expressed even at low levels of water activity Selected results of these analyses for the

good quality paddy, are given in Fig 3

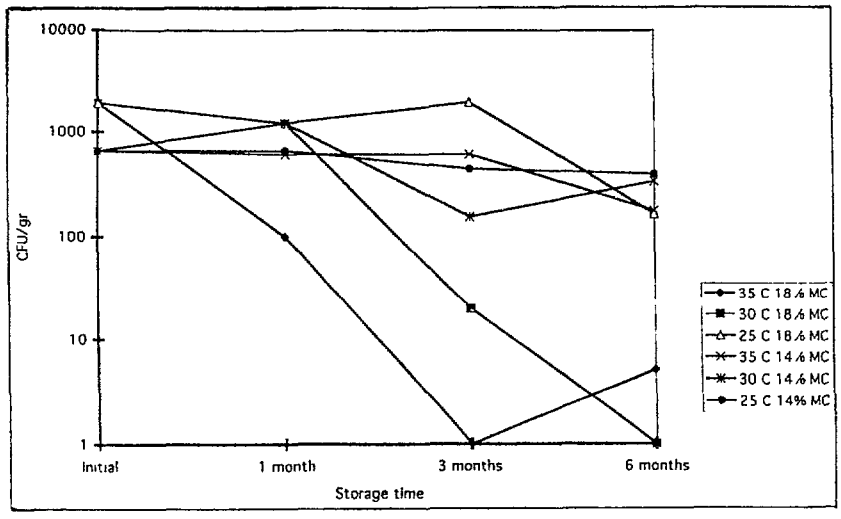
Fig 3 Fungal counts of good quality paddy taken before gas-tight sealed storage, and after one to six months of storage at 14 and 18% MC and three temperatures



ii) wheat

An identically designed trial to examine the effect of hermetic storage on the fungal count of wheat, gave similar trends in reduction of fungal count to that of paddy, though initial infection was in the order of 1,000 CFU/g (as against 100,000 CFU/g for paddy) Selected results are provided in Fig 4

Fig 4 Fungal counts of wheat taken before gas-tight sealed storage, and after one to six months of storage at 14 and 18% MC and three temperatures



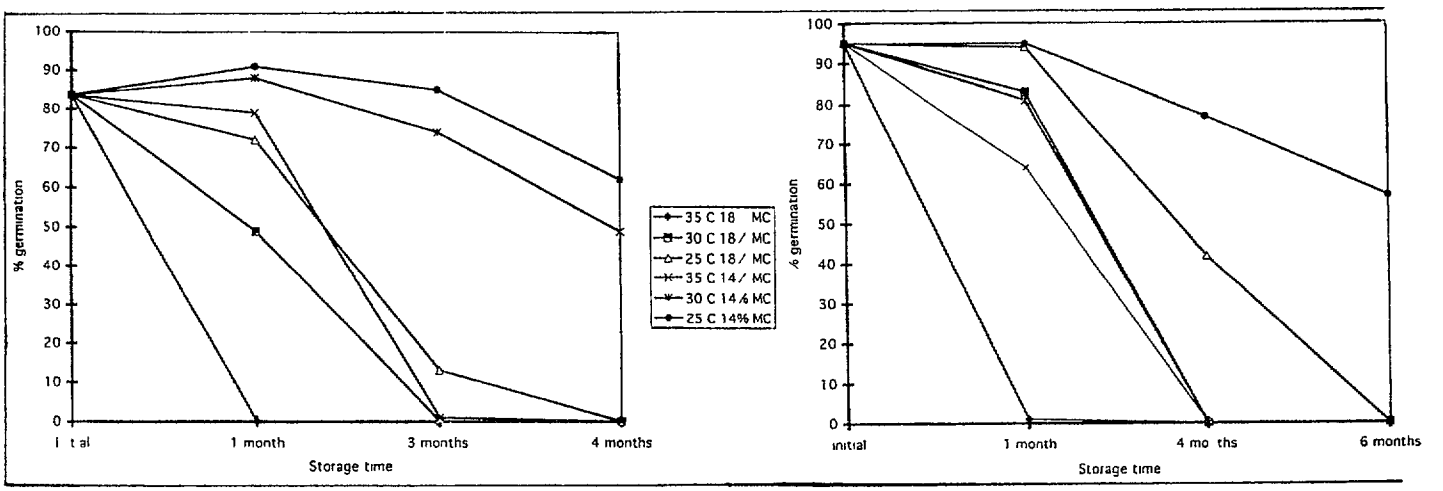
5 1 3 Germination

Although it has been shown by us that hermetically stored dry paddy retains its germination capacity well (Navarro et al 1996), to the best of our knowledge the rates of decrease in germination of paddy at intermediate MCs have not been documented Although such grain is not destined for seed, the germination index is of value in that it influences the potential of the grain for subsequent storage The low levels of germination obtained for the first consignment of paddy received in Israel, served as a warning that this was poor quality rain-damaged grain that required the experiments to be repeated in the second year

Results of germination of the good quality paddy and wheat during gas-tight sealed storage are given in Fig 5

Fig 5 Effect of 4 month exposure under gas-tight seal at three temperatures on the germination of paddy (at 14 and 18% MC), and 6 months exposure on the germination of wheat (at 14 and 17% MC)

Paddy wheat



From the Figure it is clear that for both wheat and paddy there is a negative correlation between both MC and temperature, and germination For paddy, at 18% MC and 35°C, germination fell to zero within one month, whereas at 14% MC and 25°C it was still high after 3 months Intermediate MCs and temperatures (not shown in the figure) gave a graded decrease in seed viability For wheat the capacity to retain germination was slightly greater and for 17%MC wheat at 25°C, about 40% germination was retained after 4 months

5 2 Laboratory studies on factors affecting paddy conservation under gas-tight conditions (Philippines)

Studies in the Philippines were devoted to evaluating the influence of hermetic storage on the quality conservation of paddy at different water activities Poor quality paddy was used initially (not detailed in this report), followed by good quality paddy as in the Israeli trials, and the same methodology for adjusting the paddy to different MCs was employed

5 2 1 Methodology

For the good quality paddy experiment, two trials were conducted The first was undertaken for four weeks (Jan to Feb 1997), while the second trial was continued for six months (October 1997 to April 1998) The longer storage durations of the second trial was to test the limits of the system in protecting moist paddy from quality deterioration

Experimental stock and set-up The same five MC levels were used as in Israel In addition, quality evaluations were carried out after five storage periods, namely 0, 1, 2, 3, 4 weeks for the first trial and seven storage periods, namely 0, 1, 2, 3, 4, 5, 6 months for the second trial The entire experiment was undertaken at ambient conditions
A standard experimental procedure (not described here) was used to achieve homogeneity of test material and to condition the paddy to the different MCs The conditioned paddy at the target MCs was placed separately in 3 5L glass jars with screw on metal lid and gasket seal To enable gas sampling, a hole was drilled in the lid and fitted with a plastic hose Each jar contained 1 5 kg of paddy In addition, one part of the paddy at 14% MC was kept in jars covered with filter paper, to serve as control under aerobic conditions There were three replicates for each treatment Codes given in the figures are as follows

Treatments	**Code**	**Initial conditions**
Unsealed control	UC MC14	14% MC not sealed but with filter paper cover
Sealed control	SC MC14	14% MC sealed
Treatment 1	MC 15	15% MC sealed
Treatment 2	MC 16	16% MC sealed
Treatment 3	MC 17	17% MC sealed
Treatment 4	MC 18	18% MC sealed

Parameters measured The physical parameters measured were CO_2 and O_2 concentrations, ambient temperature and relative humidity, MC and a_w The effects of hermetic storage on the quality of stored paddy were assessed using the following parameters with analysis of samples that were taken at the start, and at the end of each storage period

1 % yellow kernels
2 Minolta b* value
3 % milling recovery
4 % headrice recovery
5 Microfloral load
6 Sensory evaluation

For brevity, details of the methodology used in analysis of the first five parameters mentioned above, are not included here, but will be detailed in future publications

Prof M Del Mundo, and Angelina Felix of the Institute of Human Nutrition and Food, University of the Philippines, Los Baños Laguna conducted the sensory evaluation This consisted of an evaluation of the cooking and eating qualities of the rice milled from all the paddy samples taken at the end of each treatment The objective was to relate MC and storage duration to cooking and sensory qualities of the corresponding cooked milled rice Two kg freshly milled rice samples from each treatment were sent to UPLB after every sampling period

Cooking trials to measure optimum cooking water and other parameters were

conducted within the same day that the samples were received Sensory evaluations employing the same consumer panel (n=50) were conducted the following day Cooking and sensory assessments were conducted following the procedure of Del Mundo (1991)

Variation in terms of the cooking parameters (% height increase and cooking time), % acceptability and preference scores were obtained across MC's for the different storage periods Cooked sensory qualities such as flavor, tenderness, cohesiveness and gloss were compared among the experimental samples

5 2 2 Results and Discussion

i) Physical parameters

Carbon dioxide and Oxygen concentration Rates of O_2 depletion and CO_2 build-up within the sealed jars were very similar to those recorded by the Israeli partners and are not detailed here One aspect of the gas monitoring was to verify that the hermetic seal had not been broken so that samples for quality analysis truly reflected the target conditions

Ambient temperature and relative humidity Average ambient temperature and relative humidity recorded during the first laboratory trial were 28 7°C (23 3 to 37 1°C) and 57 5 % RH (45 5 to 69 3% RH), respectively During the second laboratory trial, the average ambient temperature and relative humidity recorded were 29 8°C (24 4 to 37 9°C) and 56 9% RH, (30 1 to 74 2% RH) respectively

Moisture Content and water activity The paddy received from procurement and prior to conditioning for the first and second trials had average MCs of 11 4% and 11 0% and germination rates of 84% and 96%, respectively

The average MCs and water activities of the different paddy treatments for both trials at the start of the experiments, are given in Table 1 Minor changes in MC were observed at various storage intervals throughout the duration of both trials in all treatments under hermetic storage The MC of the untreated controls for both trials tended to decrease This decrease in MC was anticipated because of the low ambient relative humidity, which triggered the drying effect On the other hand, the paddy in sealed jars manifested slight increments in MC this additional water being the product of respiration

Table 1 Average initial MC and a_W of paddy

	Trial I		Trial II	
Treatments	MC	a_W	MC	a_W
Unsealed C MC14	13 9%	0 79	14 1%	0 75
Sealed C MC14	13 9%	0 79	14 1%	0 75
MC15	15 1%	0 82	15 3%	0 80
MC16	15 9%	0 83	16 3%	0 85
MC17	16 9%	0 85	17 4%	0 88
MC18	18 0%	0 87	18 4%	0 91

ii) Grain quality parameters

Yellowing and b value* Changes in percent yellow kernels, as visually assessed, are shown in Fig 6 Both this and the changes in yellowness as measured by the Minolta Chroma meter, indicate an increasing trend in grain yellowing in all MC levels as storage progressed Levels of yellowing in all treatments were still acceptable and under the 2% maximum yellowing limit set for Grade 1 milled rice by the National Food Authority (NFA) standards, except for paddy at 17% and 18% MC which were downgraded to Grade 2 (>2-4% maximum yellows) after 4 months storage at 17% MC and 5 months storage at 18%

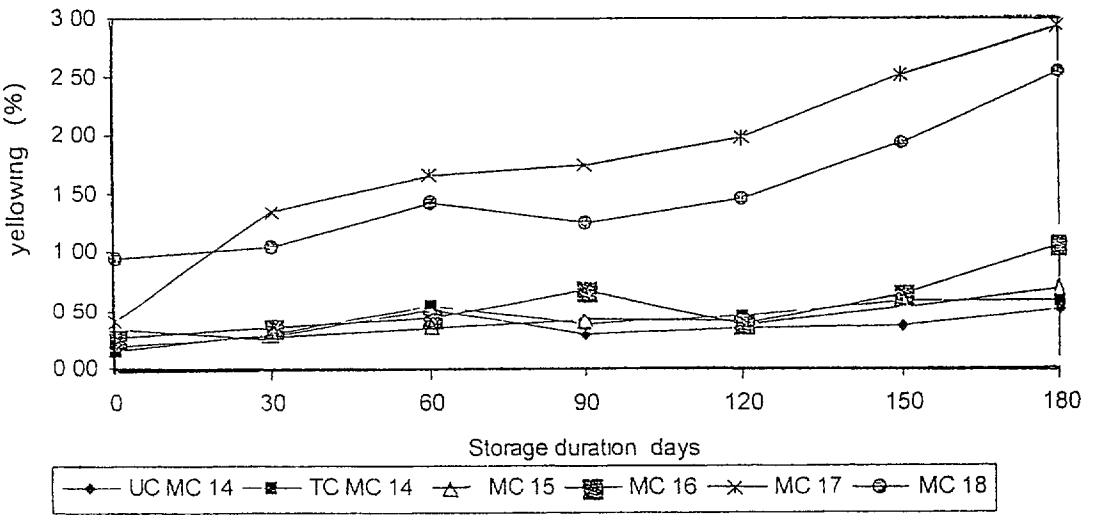


Fig 6 Changes in levels of yellow kernels in hermetically stored paddy at different MCs under laboratory conditions

Milling and headrice recovery It was noted that right from the start of the experiment, the milling and headrice recoveries were low This condition could be brought about by grain conditioning which includes re-wetting and storage at very low temperature (2 ± 1°C) This process probably caused moisture stress leading to kernel fissuring and breakage

Microfloral load The dominant fungal species observed from the samples prior to storage were *Aspergillus flavus* and *Fusarium oxysporum* Other species observed but at low incidence were *Aspergillus fumigatus*, *Eurotium amstelodami*, *Fusarium poae* and *Syncephalastrum racemosum* Fungal species such as *Eurotium chevalieri* and *Fusarium semitectum* were also isolated during the intermediate sampling periods

The average initial total percent infection in the various treatments ranged from 21% to 26% After 28 days of storage changes in total percent infection varied with MC levels Average total percent infection in paddy at the lower MCs (UCMC14, TCMC14, MC15, MC16) increased whereas for paddy at 17% and 18%MC they decreased to 18% and 13%, respectively

The paddy samples conditioned to 17 and 18% MC were observed to have high initial infections of *A flavus* (90 - 100%) and *F oxysporum* (96 7 - 100%) whereas, paddy conditioned at 14, 15 and 16% were also found infected by *A flavus* (10 -70%), *A fumigatus* (0 - 16 7%), *E amstelodami* (0 - 6 7%) *F poae* (0 - 6 7%), *F oxysporum* (0 -

60%) and *S racemosum* (0 - 3 3%)

At the end of the trial, fungal infection in sealed paddy samples at 17 - 18% MC were significantly reduced Percent fungal infection with *A flavus* was reduced to 3 3 - 30% and with *F oxysporum* to 0% Fungal infection in the sealed paddy samples at 14, 15 and 16% MC did not significantly change, perhaps because the O_2 remained at slightly higher levels during storage period

Results of the microbial analysis in the second laboratory trial (6 month duration) showed that initially, nine fungal species were found infecting the paddy, the most common species at all MC levels being *A flavus, E chevalieri, E amstelodami, Mucor circinelloides* and *F oxysporum* Other less frequent fungi were *Aspergillus niger, A fumigatus, Curvularia lunata* and *Neosatorya fischeri* During the first three months, *Eurotium* species and *N fischeri* were noted to be infecting paddy at lower MCs (14%-16%) While *A oryzae* and *Penicillium citreonigrum* prevailed in paddy at 15%-18% MC For the 4th and 5th months, *Aspergillus ochraceous* was prevalent in paddy at 15%-17% MC, while *E amstelodami* and *E chevalieri* remained infecting paddy at the lower MCs (14% and 15%)

It was shown that *A flavus* was present at all MCs throughout the storage time However, after 6 months, growth of *Eurotium* sp and *N fischeri* were suppressed Non suppression of *Byssochalmys nivea* and *Penicillium* was observed at 18% MC, implying that the modified atmosphere obtained by hermetic storage did not affect these species

Bacterial populations rose sharply after a month of storage in paddy held at 18% MC, while in the paddy at 17% MC this occurred after 2 months of holding As a result, a strong foul odor developed in these grains

<u>*Sensory evaluation*</u> (This section is part of a full, detailed report provided by Prof del Mundo and Ms Felix, in 1998, see Appendix 2 Results of the preliminary trial using rain damaged paddy is not included here)

In the trial using good quality paddy, correlation analysis disclosed no significant differences in terms of cooking time across MCs and storage durations Cooked rice aroma, taste, tenderness cohesiveness, color and gloss were negatively correlated with MC and storage duration of stored paddy These characteristics became inferior at higher MC level and longer storage period Among these attributes, aroma and flavor had the strongest negative correlation with MC and storage duration The poor acceptability and preference for cooked milled rice samples from paddy stored at 16% to 18% MC was primarily dictated by the presence of fermented smell in these samples In the raw form, wholeness of grains and color were found to have a significant negative correlation with MC and storage duration Milled rice samples from paddy stored at lower MCs had whiter shade of color and a higher proportion of whole grains compared to milled rice samples from paddy stored at higher MCs As the lengths of paddy storage increased and at the higher MCs, color of the rice tended towards a creamy to grayish shade and broken grains became more evident

5 3 Pilot scale studies on factors affecting grain conservation under gas-tight conditions

5 3 1 Permeability of liners to gases

Several plastic liner materials were especially developed for the project by Haogenplast They were analyzed for permeability to oxygen and carbon dioxide On the basis of these tests the most suitable material was chosen and a 15 m^3 storage structure was fabricated from the material

The gas-tight seal of the structure was tested by inflation and measurement of pressure decay This gave extremely good results Permeability parameters of this storage cube were then examined under field conditions by inflation with carbon dioxide when loaded with dry wheat and then applying negative pressure for measurement of rate of pressure decay These results may be compared with those of a 15m^3 Volcani cube used for dry grain storage (fig 7)

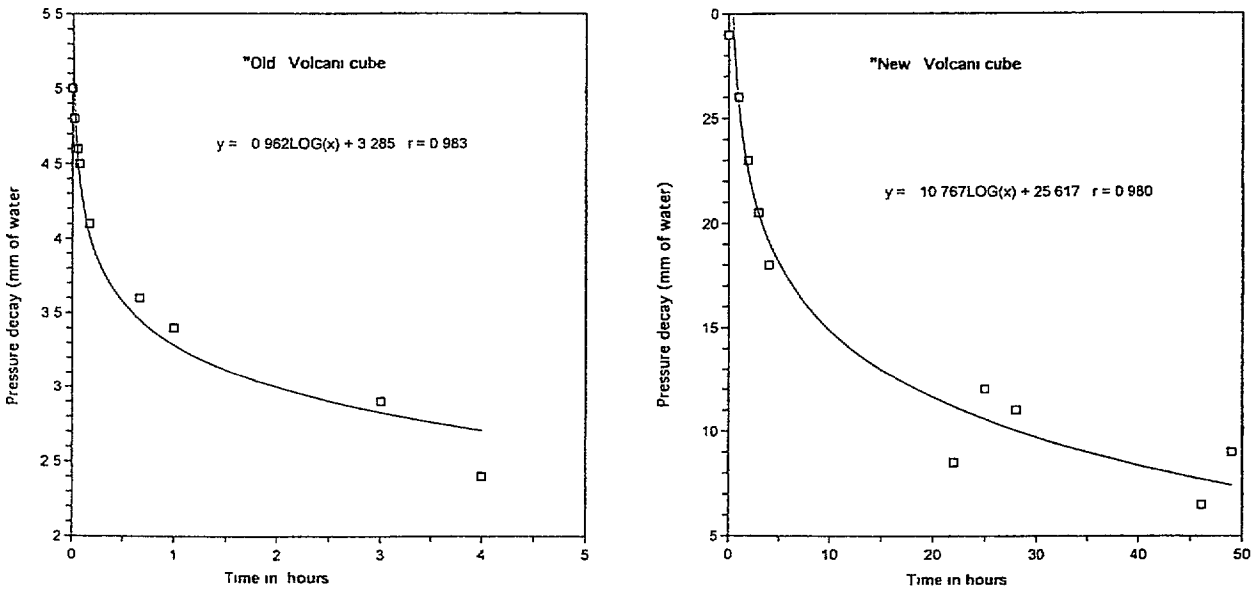


Fig 7 Pressure decay tests carried out on a standard Volcani cube and a laminated cube for evaluation of permeability indices

5 3 2 Field trial with moistened wheat

The structure was then loaded with app 10 tons of bagged wheat, after the top layer of bags had been moistened Calculations were made (based on the wheat respiration rates obtained in the laboratory) to determine the amount of wheat required to be moistened in order to obtain rapid reduction in O_2 levels as a simulation of conditions in the Philippines The required amount of wheat in the upper layer of bags was subsequently moistened to approximately 18% MC and the liner sealed to test whether oxygen concentrations could be rapidly reduced to less than 1% Although the trial was initiated under winter conditions with low ambient temperatures the results confirmed that intermediate MC grain is capable of rapidly reducing O_2 concentrations under field conditions, (see also Section 5 5 2 1)

This trial stimulated the speculation that if all the grain had been moistened to 18% MC the oxygen depletion would have been so rapid as to enable the normal PVC based Volcani cube to be used for the same purpose If this were true it would be extremely

advantageous because of the large price differential between the two structures It was decided on the basis of this trial to try to compare the "improved" and normal cube for the field trials in the Philippines

5 4 Reflective covers (Israel and Philippines)

5 4 1 Introduction One significant finding of the previous CDR project (Navarro et al 1996), was that under Philippine conditions, for dry grain stored in cubes outdoors with no shade, the diurnal temperature fluctuations of the ambient created temperature gradients within the cubes that caused convection currents to carry moisture to the top of the grain stack To overcome this an upper insulating layer of bags containing rice hulls was advocated This method effectively solved the problem but also suffered from several inherent disadvantages namely reduction in effective storage capacity of the cube, necessity to procure and transport the husks and fill the bags, and the added expense of bags not used for storing grain Under Philippine conditions this method enables safe storage for periods of up to three months For more extended time periods the wet top layer of husks should be replaced with dry husks

In this project it was envisaged from the outset that when intermediate MC grain is stored outdoors in the field this phenomenon would also occur and would probably be even more acute

In a search to find an alternative inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, the use of a knitted shade cloth as a thermal screen and formed from aluminium coated high density polyethylene threads named "Polysac - Aluminet" was investigated

Initial trials in Israel were carried out during October-December of 1996, followed by further trials both in Israel and the Philippines during the summers of 1997 and 1998

5 4 2 Methodology and Results (Israel)

A detailed description of these trials will be provided in a paper presented at the upcoming 19th ASEAN Seminar on Postharvest Technology to be held in Ho Chi Min City Vietnam in November 1999, (see appendix 3) A brief summary is as follows

Several types of woven material were tested The initial trial in Israel was directed at comparing the day-time temperature gradients at the top of storage cubes, between unprotected and protected segments of the cube Two densities of material were compared and the insulating effect of the two types was examined both when the cover was spread directly over the top of the liner and also when it was separated from the liner by a distance of 10 cm using spacers Results of this trial were inconclusive though they indicated a decrease in temperature gradient when protected by the cover Therefore a follow-up was done in which temperature measurements were recorded using data-loggers specially purchased to enable temperature gradients to be monitored at night-time, when condensation problems are more acute However, in this case, where entire covers were used using a 7-days on and 7-days off regime the problem of fixing the cover above the cube became evident To solve the problem the edges of the cover (separated from the cube by spacers) were attached to cords that were drawn down and tied to the tension straps around the cube

However, in this way the sides of the space above the cube were sealed by the cover We believe that although there was a small reduction in temperature gradients, the absence of this gap between the top surface of the cube and around the borders of the stretched cover may have resulted in trapping the heat between the cover and liner This prevented free air movement above the liner during the daytime, and may also have had a negative effect on reducing nighttime temperature gradients The final trial in Israel was designed to overcome this problem (Fig 8 c)

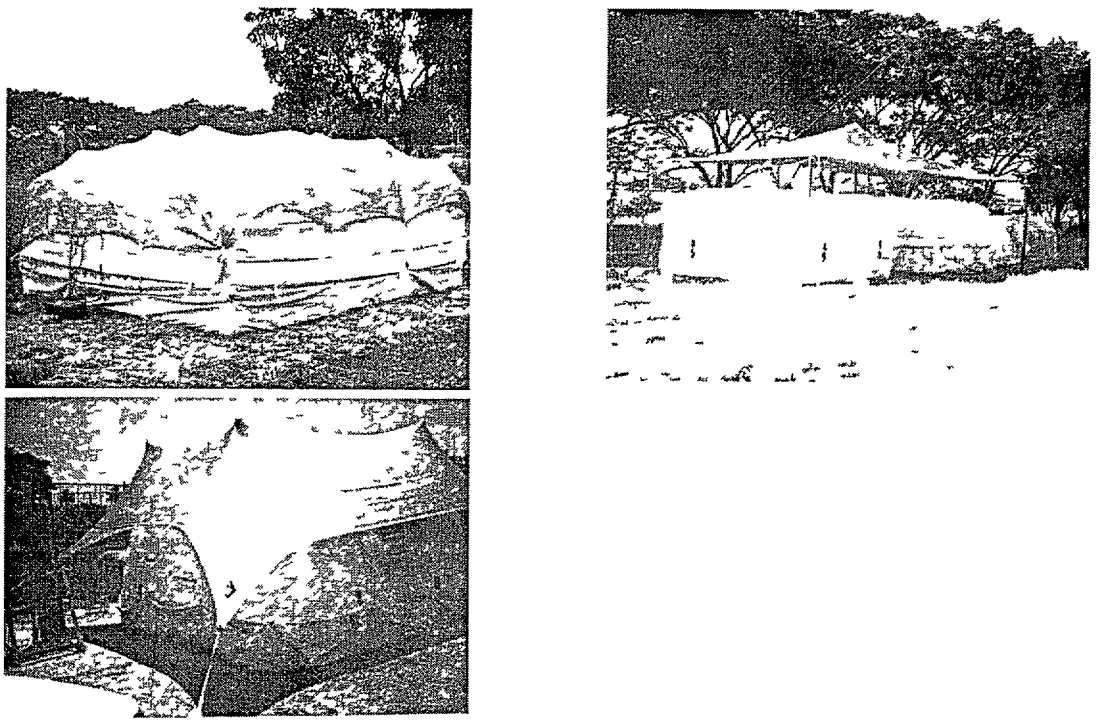


Fig 8 Reflective covers showing a) cover clamped over cube with spacers (Philippines), b) cover suspended above cube (Philippines), c) cover raised above cube with spacers (Israel)

In this trial the reflective cover was stretched over the top of the cube using 20cm spacers, and care was taken to ensure that the cover was not brought down at the periphery, but remained with a gap to permit free air movement beneath the cover The cover was removed and replaced at weekly intervals so that three alternating series of recordings were obtained A summary of the amassed data is provided in Table 2

The Table clearly shows the attenuation in daily temperature fluctuations caused by the reflective cover Over the course of the trial, the average daily temperature above the liner was about 7 degrees lower, with the cover in place, than without it and this was particularly evident during the day-time (hours of sunlight) when there was a 10 to 15 degree temperature difference

Table 2 Average weekly temperatures and temperature gradients recorded with and without a reflective cover placed above a 10 ton capacity storage cube at Bet Dagan Israel (28th March to 10th June 1998)

a) Weekly averages of 24 hour recordings

Week (1998)	reflective cover	above liner	below liner	10cm	Ambient temp	Temp gradient	Temp gradient	Temp gradient
		(A)	(B)	(C)		(A-B)	(A-C)	(B-C)
Average	With	22 7	22 3	21 7	21 6	0 4	1 1	0 6
Average	Without	26 9	26 1	23 9	22 6	2 4	4 6	2 2

b) Weekly day time averages of sunlight hours (9am to 6pm)

Week (1998)	reflective cover	above liner	below liner	10cm	Ambient Temp	Temp gradient	Temp gradient	Temp gradient
		(A)	(B)	(C)		(A-B)	(A-C)	(B-C)
Average	With	29 2	27 1	21 1	26 3	2 1	8 1	6 0
Average	Without	43 5	35 8	23 3	26 7	7 8	20 3	12 5

c) Weekly night time averages (7pm to 8am)

Week (1998)	reflective cover	above liner	below liner	10cm	Ambient Temp	Temp gradient	Temp gradient	Temp gradient
		(A)	(B)	(C)		(A-B)	(A C)	(B-C)
Average	With	18 1	18 9	22 0	18 3	-0 8	-3 9	3 2
Average	Without	18 3	19 5	24 3	19 6	1 2	-6 0	-4 8

The data obtained indicate that there is a continuous rhythm of convection currents due to temperature gradients when during the night moisture is transported to the surface layers and during the day-time the surface layers lose moisture as they heat up Under Israeli climatic conditions we showed (Navarro et al , 1996) that throughout the year there is no marked net-moisture transfer to the surface in the storage cubes, and no special precautions need be taken However previous trials carried out in the Philippines showed that there was a continuous process of moisture transfer to the surface due to the fact that the net moistening effect at night was greater than the net drying effect during the day Therefore it was evident that if this reflective liner is to meet the requirements for the storage of dry grain (as a replacement for the insulating top layer of agricultural wastes as a requisite in the present storage method) or for storage of intermediate moisture-content grain under tropical conditions field trials had to be undertaken in the Philippines including an examination of grain moisture content at the top surface after storage

5 4 3 Methodology and Results (Philippines)

The first two trials in the Philippines also revealed the attenuating influence on temperature gradients due to the reflective covers when properly positioned and these results are not reported here This summary is confined to the third trial since it incorporated an examination of MCs at the top of the stacks at the beginning and end of storage **(see also Section 5 5)** This trial was carried out in conjunction with a field trial for storage of moist paddy using the low permeability cube (6 months) and the standard cube (3 months) to

evaluate quality An additional cube containing dry paddy at 14% MC, (5 months) was set up under a reflective cover but was not monitored for temperature gradients

In this trial a single layer reflective cover was erected over both cubes using a series of poles and guy ropes to create a tent shaped cover that also partially protected the sides (Fig 8b) Temperatures were logged hourly on a 24 h basis above the liners, below the liners, 10 cm within the upper grain layer, and in the central core of the stacks, thus permitting an evaluation to be made on the effect of the covers on temperature gradients during the night-time hours

Calculations based on temperatuie read-outs show that if 18% MC paddy has an equivalent EMH of 92% RH the water content of the air at 10 cm depth, would be about 25 1g/m^3 at 27 6°C If this air rises due to the night-time temperature gradient and cools at the surface below the liner to 25 C then at 100% RH it would contain 23 1g/m^3 Namely there would be a condensation of 1 8 gm for every cubic meter of air reaching the upper surface However, this represents the worst-possible-scenario Although the calculations show that for most of the night duration, air at 92% RH (=18% grain EMC) would become saturated when in contact with the upper plastic liner, the very small temperature gradient would produce only feeble convection currents In order to evaluate the net effect of moistening of the surface layer at night-time and drying during the day-time, the MCs at the top of the stack were examined after 3 and 6 months These findings are given in Tables 3 and 4 A full report of this trial is given elsewhere

Three months storage From Table 3 it can be seen that after 3 months, moisture migration had caused an increase of 4% MC in the top layer and 2% MC in the second layer Since MCs above 18% (EMH = 92%) enable the development of yeasts and bacteria that cause rotting and the development of unpleasant odors, the organoleptic characteristics of the paddy were also seriously affected (see field trial report by Prof del Mundo Appendix 3)

Table 3 Average moisture contents of intermediate moisture content paddy hermetically stored in a Volcani cube for 3 months

Position	Three composite samples	Beginning	3 months	Composite sample from all bags in each layer of stack	Average 3 readings
	Average 6 readings	22-Nov-98	23-Feb-99	23-Feb-99	
Top (1)	1	18 0	19 3	1 (top)	22 0
	2	17 9	19 8	2	20 4
	3	18 0	20 1	3	18 0
				4	18 0
Middle (4)	1	18 0	17 2	5	18 3
	2	18 0	17 3	6	18 3
	3	18 2	17 5	7 (bottom)	18 0

Table 4 Average moisture contents of intermediate moisture content paddy hermetically stored in a Volcani cube for 6 months in the Philippines

Position	Three Composite samples Average 6 readings	Beginning	6 months	Composite sample from all bags in each layer of stack	Average 3 readings
		22-Nov-98	21-May 99	21 May-99	
Top (1)	1	18 3	24 8	1 (top)	28 5
	2	17 5	28 6	2	21 0
	3	17 6	21 4	3	18 2
				4	17 7
Middle (4)	1	18 0	18 3	5	17 0
	2	17 9	18 6	6	17 0
	3	17 6	18 4	7 (bottom)	16 7

Six months storage Table 4 shows that convection currents caused an even greater increase in MC of the upper layers for the 6 month storage period However, here again the accumulation of moisture was only noted in the top two layers The acceptability parameters (very strong fermented odors) of the rice milled from this paddy were so low that analysis of the cooked rice was not deemed necessary (see del Mundo Report Appendix 3)

Dry grain storage This cube was only protected by the reflective cover, while the normally employed protective upper layer of bags containing rice husks was not used At the end of the 5 month storage period, the stack was opened and examined, and although no detailed examination of moisture contents by stack layer was undertaken, the spot tests at the top of the cube revealed that no perceptible increase in moisture contents had occurred and the grain was dry throughout the stack

5 5 Field Trials - Philippines

5 5 1 Materials and methods

Two outdoor trials were carried out at the BPRE, CLSU Compound, Muñoz, Nueva Ecija, both to test the flexible liner as an alternative storage system for preserving wet grain quality under Filipino conditions, and to determine the effect of reflective covers in reducing temperature fluctuations as reported in Section 5 4 Table 5 summarizes the initial field trial parameters

Experimental stocks In the first trial, the paddy used was freshly harvested IR-64 variety certified seed from a single farm lot The MC ranged from 20 6 % to 21 3% A day after receipt, the stock was sun dried to 17 0 to 18 3%MC The following day, two hundred and six bags were stacked in the Volcani Cube

In the second trial five hundred bags of freshly harvested IR-64 variety certified seeds were purchased The MC of the stock at procurement was 22 0% to 24 0%, and after mechanical drying ranged from 17 8% to 18 4%

Table 5 List of field trials carried out to determine the storability of intermediate moisture paddy in hermetic storage in the Philippines climate conditions

Field Trial #	Stack Code	Storage structure	Treatment		No of Bags	Capacity (tonnes)	Initial MC Range (%)	Duration (days)
			Gastight	Control				
I	S1	Laminated Volcani cube	X		206	7 64	17 0 18 3	30
I	S2	Ordinary tarpaulin		X	20	0 88	13 6 14 5	30
I	S3	Ordinary tarpaulin		X	20	0 74	17 0 - 18 3	30
II	S4	Volcani cube	X		184	9 87	17 8 18 4	93
II	S5	Laminated Volcani cube	X		180	9 83	17 8 - 18 4	180
II	S6	Ordinary tarpaulin		X	20	0 96	17 8 - 18 4	180*
II	S7	Ordinary tarpaulin		X	20	0 95	13 8 - 14 4	180*

* samples were taken on the 93rd day of storage at the top and along the periphery of the stack to serve as control for S4

Preparation of storage site and construction of stacks This was carried out according to standard procedure developed earlier (see Navarro et al , 1996) The experimental paddy was bagged in 50-kg polypropylene sacks For the first field trial, the paddy was stacked in a $15m^3$ laminated Volcani cube tailored from heavy-duty sheeting, UV-protected, of food-grade quality similar to the one pre-tested in Israel (S1) The laminated Volcani cube was further covered with a reflective awning (Fig 8) In addition, two control stacks of 14% MC coded as S2 and 18% MC coded as S3 were piled on wooden pallets and covered with ordinary white tarpaulin sheets only

For the second trial, a non-laminated (coded S4) and a laminated (coded S5) Volcani cube were used to store paddy at 17-18% MC Two stacks of 18%MC (S6), and 14%MC (S7) served as controls All the Volcani cubes whether laminated or not were covered with reflective awnings, whereas the control stacks were covered only with tarpaulins

Temperature and gas concentration monitoring Six thermocouple cables and two plastic tubes were installed at different locations inside the cubes to monitor grain temperatures and gas concentrations, respectively Changes in CO_2 and O_2 concentrations were measured daily using a GOW-MAC gas analyzer and a David Bishop OxyChek 2, Oxygen meter respectively

Sampling and parameters Initial samples were collected during the building of the stacks and final samples were collected and analyzed to determine changes in the quality of stored paddy The following physical and quality parameters were recorded

1 % MC and a_w
2 % yellow kernels and Minolta b* values
3 % milling recovery and % head-rice recovery
4 Insect infestation
5 Microfloral load
6 Sensory evaluation (for cooked and uncooked milled rice)

The MCs of the paddy samples were monitored using a Dickey John Multi-Grain Tester The a_w were measured using a Novasina MS1 Defensor Percent yellow kernels were

determined from the ratio of visually yellow kernels and the weight of milled rice The Minolta b* value was measured with a Minolta Chroma Meter CR-110 For the assessment of milling recovery, wet paddy samples were dried first using the EUROTHERM Laboratory Mechanical Dryer and then milled using a Satake Grain Testing Mill

The sensory evaluations of the field trials were conducted as in the laboratory evaluations by Prof del Mundo and Ms Felix, of UPLB (see Appendix 3) The evaluations were divided into two "activities"

Activity 1 A comparative analysis of cooking and sensory qualities of cooked and uncooked milled rice from wet paddy (18% MC) before storage and at the end of storage in the Volcani cubes ((S4, after 3 months and S5 after 6 months), and from control stacks under tarpaulins (S6, S7) at initial MCs of 14 and 18% respectively Composite samples were obtained from the middle (4th) layer of the Volcani cube stacks while for the controls, the samples were randomly obtained from the different sides of each of the stacks at the two sampling periods The rice samples were milled at BPRE as described above and 2kg milled rice from each 3 kg paddy sample were then dispatched to UPLB

Activity 2 An evaluation after three months (S4) and 6 months (S5) taken from the various stack levels/layers of the Volcani cubes in order to differentiate between layers using the same quality indices as in activity 1 In this case, composite samples from each layer were taken and dried down to 14% MC before milling The topmost layer for both stacks was numbered as level 1 and the bottom layer as level 7

All samples from both activities were assessed in terms of cooking parameters and all samples of uncooked milled rice underwent sensory evaluation For the cooked milled rice, only samples from three months storage were subjected to sensory evaluation The strong unacceptable fermented odor during the determination of the cooking parameters of the samples from the six months storage stack led to the suspension of their sensory evaluation

Cooking and sensory assessments were conducted according to the procedure of Del Mundo (1991) Optimum cooking water was established for each sample Cooking parameters included % height increase and cooking time Sensory qualities evaluated for the raw milled rice were % acceptability, preference score, aroma, color, gloss, wholeness of grains, brittleness of grains, and grain translucency For the milled cooked rice, evaluations were for % acceptability, preference score, aroma, flavor, tenderness, cohesiveness, color and gloss

5 5 2 Results and discussion

5 5 2 1 Physical parameters

Carbon dioxide and oxygen concentration During the first field trial, the O_2 level in the laminated Volcani cube S1 decreased to less than 1% two days after sealing This level was retained until the stack was opened on the 30th day Meanwhile the CO_2 concentration reached a maximum of 26% after nine days

For the second field trial, O_2 concentrations in the two sealed stacks also decreased to less than1% two days after sealing and this was retained until the cubes were opened for

sampling (After stack S4 was opened for MC sampling after 30 days, the O_2 level returned to less than 1% 3 days after sealing) Meanwhile, the highest CO_2 concentrations of 29% (S4) and 31% (S5 - see Fig 9) were attained after 71 and 48 days, respectively **These findings clearly show that for paddy at 18%MC, the standard Volcani cube also enables paddy respiration to reduce and maintain O_2 concentrations to below 1% within 48 hours**

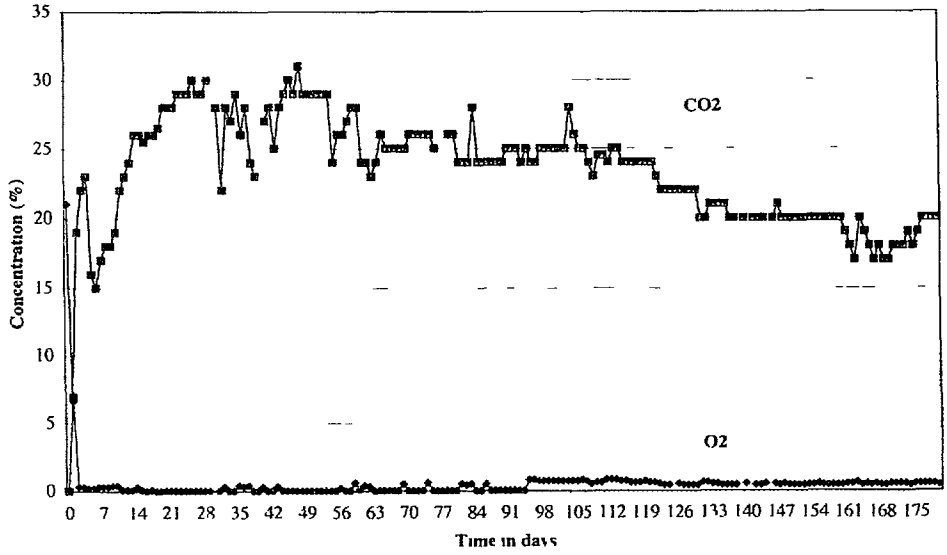


Fig 9 Gas concentrations within the sealed laminated cube (S5) during 6 months of storage

Temperature Grain temperatures recorded during the field trials revealed no indication of self heating Observations also showed that during day-time, temperatures above and below the liner were consistently lower than that of the ambient, this being attributed to protective effect of the reflective cover by avoiding sorption of solar energy during the day

Moisture content

Trial 1 The average MC in the laminated cube S1 had increased from 16 9% to 17 5% at the end of 31 days This we attributed mainly to grain respiration Also, there was evidence of moisture migration where 16 bags at the topmost layer of the stack were visibly wet and MC had increased to 18 5% In contrast, the average MC of the control stack S2 decreased from 13 9 to 11 5% while that of S3 decreased from 16 7% to 13 4% after 31 days (These reductions in MC may be attributed to the low ambient RH prevailing during the trial and the small size of the control stacks at 20 bags each, that facilitated natural ventilation The large surface area to volume ratio of the small stack may also have facilitated this drying phenomenon)

Trial 2

Initial MCs of the stacks are given in Table 5 When the Volcani cube S4 was opened after 93 days, clear evidence of condensed moisture was observed On the average, the MC at the top layer had increased by 1 7% The four faces of the stack (N, W, S, E) indicated signs of moisture migration and moisture condensation However, the MC at the middle layer of the stack had decreased by an average of 0 8% Again, the average MC of

the control stacks S6 and S7 had decreased to 11 8% and 11 0%, respectively after 93 days, though, germinated seeds were observed in S6 in almost all the bags despite the eventual reduction in MC, (this probably resulting from strong condensation beneath the tarps)

After 6 months of sealed storage, the laminated Volcani cube S5 incurred heavy moisture condensation which damaged the top three layers and caused grain deterioration The grains in the top layer increased in MC by 7 1% Darkened, rotten and foul-smelling grains were found on the affected bags At the sixth month sampling, both control stacks S6 and S7 encountered a further reduction in MC as an effect of natural drying due to high ambient temperatures

5 5 2 2 Grain quality parameters

Yellowing and b value*

Trial 1 The average initial yellow kernels of sealed stack S1 and control stacks S2 and S3 were 0 13%, 0 09% and 0 06%, respectively After 31 days of storage, yellow kernels in S1 significantly increased to 0 66%, the highest level being at the dampened topmost layer which increased to 1 26% In the control stacks S2 and S3, the yellow kernels significantly increased to 0 33% and 0 49%, respectively However, as in the lab experiments, the increase in yellow kernel levels did not exceed the 2% maximum limit set by NFA for Grade 1 milled rice In the same manner, the average b* value of S1 increased from 9 6 to 10 6 the highest being at the dampened topmost layer which was 11 2 In S2 the b* value at 9 7 did not change, and in S3 it increased from 9 7 to 10 2

Trial 2 The same trend was observed for sealed stack S4 where the average yellow kernels increased from 0 9% to 1 1% and the b* value from 9 6 to 10 8 after 93 days of storage During the same period yellow kernels and b* value in control stack S6 increased from 0 9% to 6 5% and from 9 7 to 11 2, respectively, while in S7, yellow kernel and b* value increased from 1 2% to 2 4% and from 9 5 to 10 2, respectively

After 180 days of storage, sealed stack S5 was found to be heavily damaged with an increased average yellow kernel and b* value from 1 2% to 25 3% and from 9 8 to14 3, respectively at the top layer of the pile Yellow kernel and b* value also increased from 1 0% to 14 4% and from 9 9 to 12 8, respectively at the middle layer of the pile Yellowing and b* value in S6 and S7 increased further to 7 5% and 11 9 and 2 6 % and 11 2, respectively The observations in both trials confirm the laboratory findings (Section 5 2 2)

Milling and head-rice recovery

Trial 1 The average milling recovery of S1 decreased from 65 1% to 59 7% while the control stacks S2 and S3 decreased from 65 2% to 60 0% and 65 7% to 60 1% respectively after 31 days of storage Likewise, head-rice recovery of S1 decreased from an initial 80 7% to 65 9%, 62 4% and 38 8% at the bottom, middle and top layers, respectively while S2 and S3 decreased from 79 7% and 80 6% to 69 1% and 67 8%, respectively The marked decrease at the top layer of S1 may be attributed to the increase in MC as a result of convection currents to the surface and condensation

Trial 2 In contrast to trial 1, the average milling recovery of sealed stack S4 increased from

65 0% to 66 4% after 93 days of storage during the second trial, and the control stacks S6 increased from 64 7% to 67 3% and S7 from 66 1% to 67 7% during the same period This may be attributed to biological aging which usually occurs after 1-3 months of storage After 180 days storage, the average milling recovery of Volcani cube S5 decreased from 65 6% to 59 8%, while head-rice recovery decreased from 80 2% to 79 1% In contrast, milling and head-rice recovery of control stacks S6 and S7 increased to 65 6% and 90 2%, and 67 0% and 89 6%, respectively as a result of the drying phenomenon mentioned previously

Insect infestation At the end of storage all control stacks in both trials were infested by the following species of stored product pests *Rhyzopertha dominica, Sitophilus oryzae, Tribolium castaneum* and *Cryptolestes* sp Ambient temperatures and relative humidities during the two trials favored development of these stored product insects At the end of both trials, the sealed stacks in the Volcani cubes revealed no infestation

Microfloral load

Trial 1 The initial total percent fungal infections in Volcani cube S1, and control stacks S2, and S3 were 12%, 12% and 10%, respectively After 30 days, fungal infection in S1 decreased to 3% while the total percent fungal infection in S2 and S3 significantly increased to 15% and 20% respectively

Trial 2 In this trial, the stocks of paddy were initially found to be infected with *Aspergillus flavus, Curvularia lunata, Penicillium citrinum* and *Neosatorya fischeri* Overall, the final results indicated that after three months of gas-tight storage, the percentage occurrence of the above fungi had significantly decreased while after 6 months storage, the atmosphere inside the cube was able to suppress totally the growth *of A flavus, C lunata, P citrinum* and *N fischeri*

On the other hand, bacterial counts revealed a significant increase in the top layer of the paddy stored for 3 months Visual observation showed that microbial growth was high especially in the peripheries and topmost layer of the bag This was probably due to the increase in moisture as evidenced by moisture migration to the uppermost layer of the stack

From the paddy stored for 6 months, it was noted that the population of bacteria had significantly decreased Possibly the prolonged high CO_2 concentration was detrimental to the growth of bacteria since most food spoilage organisms appear to be sensitive to high levels of CO_2 (Pitt and Hocking, 1997) However, these findings did not correspond with those of the laboratory trials where bacterial counts were still high after 6 months (see section 5 2 2)

Sensory evaluation

Activity 1 **Cooking parameters** Initial samples from all stacks showed that the optimum rice to water ratio was 1 1 25 (80 g milled rice to 100 ml water) This ratio did not change during storage There was no significant difference in percent height increase of the cooked rice (used to indicate volume expansion) among samples during each storage period Percent height increase ranged from 146 9% to 221 4% Cooking time ranged from 15 4 to

18 4 minutes revealing an insignificant increasing trend in cooking time as paddy storage was prolonged

The cooked and uncooked qualities of the rice samples at 14% and 18% MC taken initially from the control stacks under tarpaulins (S6, S7) and the18% MC paddy from the sealed Volcani cubes (S4, S5), were similar After three months of storage, the tenderness and cohesiveness of the cooked rice from the different set-ups remained similar There were also no significant differences in uncooked milled rice qualities such as wholeness of grains, grain translucency and grain brittleness across storage set-ups and duration Samples taken from the Volcani cube (S4) however had become inferior in terms of the other characteristics There was a decrease in the overall rating for cooked rice flavor, color and gloss from initial time to third month of paddy storage Similarly, the rating for uncooked milled rice color and gloss consistently declined after three and six months for the paddy stored in the Volcani cubes

The characteristics most highly affected were aroma, percent acceptability and preference scores of the cooked and uncooked milled rice samples

After 3 months, **aroma** of the sample from the Volcani cube (S4) was significantly inferior to the control samples (which had rapidly dried due to ambient ventilation as explained pieviously) Off odor, specifically a fermented smell was perceptible in both the cooked and uncooked milled rice Aftei six months storage, the milled cooked rice of samples taken from the Volcani cube (S5), were no longer presented for sensory evaluation due to a highly distinct fermented smell recorded during the cooking trials

Acceptability as judged by two sensory panels (one from UPLB and one from a farming community) gave a mean of 35% acceptability for the cooked rice, and 51 6% for the milled uncooked rice derived from samples taken from Volcani cube S4 after three months storage These percentages weie significantly lower than the acceptability of controls S6 and S7 The sample from S7 originally at 14%MC had a mean acceptability of 95% in the cooked form and 91 7% when uncooked The sample from S6, originally at 18%MC, had a mean acceptability of 90 0% and 84 7% in cooked and uncooked forms, respectively After six months of storage, only three judges from the panels indicated acceptability for the raw sample of wet paddy stored in S5

For **Preference scores** which rank the choice levels, a positive number indicates generally-accepted, and a negative number indicates generally-rejected Samples S4 and S5 from the cubes received a consistent negative score in the cooked form as opposed to the control samples S6 and S7 Similarly, there was a notable decrease in preference score of uncooked milled rice in S4 and S5 from the initial test to three months and to six months of storage Although samples from S6 and S7 were generally similar in terms of the different cooked and uncooked rice qualities, in terms of overall acceptability and preference scores, S7 (originally at 14%MC) was better than S6 (originally at 18%MC) after three and six months storage

Scores **for color, gloss, flavor, tenderness, cohesiveness, wholeness, brittleness,** and **translucency** of the samples were also made, but although of value in themselves, they are not presented here as they are subservient to the scores for acceptability and preference

Activity 2 (Comparative analysis of the seven layers in the sealed Volcani cubes S4 S5)
Cooking parameters Optimum cooking water was the same for the seven samples during the two storage periods A rice to water ratio of 1 1 25 (80 g milled rice to 100 ml water) was established for all samples at both 3 and 6 months storage Percent height increase and cooking time were similar across samples during each storage period though a diminishing trend in height increase and an increasing trend in cooking time were noted as storage was extended from three to six months

A difference in **acceptability** scores was registered by the two groups of consumer panels particularly in terms of milled cooked rice quality The samples from all layers were rated as unacceptable by one panel (UPLB staff) while the other panelists accepted the cooked rice from S4 except those from the two topmost layers In the uncooked form, both sets of consumer panelists indicated acceptability for samples coming from layers 3 4 and 7 during the third month Both sets of panelists also rated the uncooked samples from all layers as unacceptable during the sixth month (S5)

With regard to **preference,** panelists unanimously rated the samples from layer 3 to 7 as the best of the seven layers The rating was both for cooked and uncooked milled rice samples stored for 3 months The milled rice sample from layer 7 was rated as the best sample in both cooked and uncooked forms After six months of paddy storage, the samples were no longer presented for sensory evaluation in the cooked form The samples had distinct off odor and the laboratory staff already refused to taste the samples presented to them during the optimum cooking water determination Only the uncooked milled rice from seven layers were presented to the panelists and all were rated unacceptable

Aroma The major drawback of the samples from the top layers during months 3 and 6 was their off odor/fermented smell During month 3, fermented smell was distinct in samples from layers 1 and 2 Off odor of lesser intensity was noted for all other samples Between cooked and uncooked milled rice forms, the intensity of the fermented smell was stronger in the cooked form After six months, the off odor/fermented smell became highly perceptible in all samples including those in the uncooked form

A slight variation across samples in terms of uncooked rice characteristics like **color, gloss, wholeness** of grains, **brittleness** of grains and grain **translucency** were noted during month 3, as was the case for month 6 Color of the uncooked milled rice grains however notably changed from creamish white to yellowish after six months for samples from layers 3 to 7and the yellowish color of the samples from layers 1 and 2 during month 3 were further intensified during month 6

Overall, among the samples from the seven layers, the scores and descriptions for the sensory attributes were higher and/or better for samples in the lower layers The sample from the lowest layer of the three months storage (S4) was still acceptable in both cooked and raw forms to the panel comprising a rice farming community However, regardless of layer, a duration of six months was deemed inappropriate for hermetic storage of paddy at 18%MC

5 6 Summary and Conclusion

From the above laboratory and field trials, it was agreed among the project

investigators that the following storage durations can be recommended for intermediate MC storage of paddy in hermetically sealed Volcani cubes

For 18% and 17%MC paddy storage can be prolonged for one month Perception of a fermented smell was very evident in cooked form after 2 months Other cooked qualities such as flavor, color and gloss as well as the raw qualities like color, wholeness of grains and translucency became inferior beyond one month of paddy storage

For 16% MC paddy - storage can be extended to two months Significant negative changes in cooked rice aroma as well as in such qualities as color and gloss in both cooked and raw forms were observed at above two months of paddy storage Other sensory qualities slightly changed after more than two months of storage

For 15% MC paddy - storage can be extended to three months Slight changes in sensory qualities with an off-odor slightly perceptible in the cooked form were noted after three months of storage

Paddy at 14% MC showed remarkably good sensory attributes even at three months which is still the recommended duration for paddy storage In fact in a study by del Mundo (1995) it was shown that IR64 paddy stored for one year at 12%-14% MC at ambient conditions had comparable sensory qualities to paddy stored for three and six months

The hermetic storage under hypoxic conditions of about 1% O_2 or less, needed to arrest mold development, can be obtained using a well sealed standard Volcani cube The moisture migration phenomenon experienced in outdoor storage, which is exacerbated at intermediate MCs, can be strongly reduced using reflective covers, provided they are correctly placed over the cubes

6 Impact, Relevance and Technology Transfer

A previous joint CDR project (C7-053) has facilitated implementation of the present policy of the Philippine government which is directed at providing small scale farmer cooperatives with on-site storage units so as to decentralize storage of the national grain reserve as well as provide rural communities with a higher level of food security In 1998, about 200 units of these storage structures were purchased and distributed to farmers' cooperatives nationwide Presently, 300 additional storage units have been purchased by the government to mitigate the effect of La Niña To date this concept of sealed storage to protect dry grain from insect infestation has been widely promoted by BPRE and Fumitechniks through an intensive training program of on-the-spot demonstrations and courses It is anticipated therefore that the findings of this project can be translated into practice by dove-tailing this technology into the recently developed concept of storage in flexible liners Policy decisions may have to be made in the light of these findings, but should the concept of storage of intermediate MC grain be adopted, even a one-month delay after harvest, before paddy must be dried or consumed should have a revolutionary effect on harvest losses, farmer income and food security

The project has had a stimulating effect on the activities of BPRE whose central role in postharvest activities of the Philippines cannot be over-emphasized Funding has enabled the purchase of equipment essential for carrying out research into hermetic and controlled atmosphere (CA) storage At present a member of BPRE (Ms Glory Sabio) is undertaking

PhD studies in the Department of Stored Products at the Volcani Center as a direct outcome of this cooperation Lastly, it was only through the CDR funded projects that cooperation reached a level where ARO was chosen by BPRE for special citation - "in recognition of ARO's contribution in hastening the development of the country's postharvest industry by supporting research and development activities responsive to the needs of the agricultural sector"

7 Project Activities/Outputs

Investigators of the project attended and presented relevant papers at the following conferences

1) International Conference on Controlled Atmospheres and Fumigation, held in Cyprus, April 1996
2) 18th ASEAN seminar on grains postharvest technology held in Manila, March 1997
3) 7th International working Conference on Stored-product Protection, Beijing, China Oct 1998

Project meetings/visits

1) 1995 Drs Donahaye & Navarro to BPRE (during grain storage course funded by Israeli government) followed by National Seminar on Grain Storage Technology and Food Security
2) 1996 Ms Caliboso to ARO
3) 1997 Dr Donahaye (private funding) and Dr Navarro to BPRE and UPLB
14) 1999 Dr Andales to ARO (September)

8 Project Productivity

A considerable amount of the early experimental work needed to be repeated both in the Philippines and Israel, due to the purchase of paddy which later was revealed to be of sub-standard quality However the project did cover the major objectives and included the development of reflective covers which did not form part of the original work plan but emerged as an essential addition The development of the descriptive model could not be completed in time but a Stella language simulation model has been set up and the experimental data required to verify the model has been largely gathered

9 Future Work

The outcome of this study will depend largely on decisions by policy makers and in-depth extension activities We believe that much remains to be done in the introduction of environmentally friendly storage solutions to developing countries, and that hermetic storage at the cooperative and small farmer level is one of the most promising courses of action for providing food security in the 21st Century

10 Literature cited

Andales S C 1987 Overview of drying technology in the Philippines ESCAP/RNAM Workshop on design of drying and milling equipment Laguna Philippines November 1987

Anon 1988 Yellowing of rice can be avoided NAPHIRE Techno Update 1 1 page 5

Anon1996 National Grains Standards for Rice and Corn National Food Authority page 11 – 14

Bermundo A G and R T Quiambao 1984 Socio-economic study on the utilization of mechanical grain dryers NAPHIRE Techno Bulletin No 10 20pp

Diawara B B Chagnier and D Richard-Molard 1986 Oxygen consumption by a wet grain ecosystem in hermetic silos at various water activities Pp 77-84 Eds E Donahaye and S Navarro Proc 4th International Working Conference on Stored Product Protection Tel Aviv Israel

Del Mundo AM 1995 Relationship between cooking vessels rice quality and Consumer Preferences Terminal report IHNF CHE UPLB

Del Mundo AM 1991 Guidebook on the Sensory Evaluation of Rice Makati Metro Manila Technology and Livelihood Center

Donahaye E S Navarro A Ziv Y Blauschild and D Weerasinghe 1991 Storage of paddy in hermetically sealed plastic liners in Sri Lanka Trop Sci 31 109-121

Donahaye E J Andales S C Chernoguz, D , Navarro S Azrieli A and Miriam Rindner 1998 Respiration rates of paddy at different temperatures and moisture contents In Proc 18th ASEAN Seminar on Grains Postharvest Technology 11-13 March 1997 Manila Philippines pp 145 152

Hocking A D 1991 Effects of fumigation and modified atmosphere storage on growth of fungi and production of mycotoxins Paper presented at the International Conference on Fungi and Mycotoxin in Stored Products Bangkok Thailand April 1991

Lorenzana J J 1985 Field trials on the performance of selected post harvest facilities installed in village farmers association in the Philippines Proc 8th ASEAN Technical Seminar on Grain Post Harvest Technology Manila Philippines pp 359-370

Matsuda J K Ito Y Ikeuchi and T Yoshida 1974 A new conditioning method with half-dried rice storage and its effects on rice quality I Qualities of half dried rice in temporary storage Jr Soc Agric Mach Jap 35 399 405

Mendoza E and R Quitco 1984 Quality deterioration and value loss in grain In Coming to grips with the wet season grain handling problems in Southeast Asia ACPHP Manila pp15-20

Mendoza E A C Rigor C C Mordido JR and A A Marajas 1982 Grain quality deterioration in on-farm level of operation In Progress in Grain Protection Proc 5th Annual Grains Post harvest Workshop Chiangmai Thailand pp 107-117

Mendoza M E A C Rigor R T Quitco and L L Ilag 1984 Grain quality deterioration in on-farm level of operation NAPHIRE Technical Bulletin No 1, 14pp

Navarro S and E Donahaye 1985 Plastic structures for temporary storage of grain pp 189 194 Eds Semple R L and A S Frio Proc 8th ASEAN Technical Seminar on Grain Post Harvest Technology Manila Philippines

Navarro S and E Donahaye 1988 Storage of emergency grain supplies 17 pp Issues in International Food Security A Faculty Development Workshop Colgate University Hamilton N Y

Navarro S Donahaye E Caliboso F M and Sabio G C 1996 Application of modified atmospheres under plastic covers for prevention of losses in stored grain Final Report CDR USAID Project C7 053 32 pp

Navarro S E Donahaye Y Kashanchi V Pisarev and O Bulbul 1984 Airtight storage of wheat in a P V C covered bunker In Ripp B E et al (Eds) Controlled Atmosphere and Fumigation in Grain Storages Elsevier Amsterdam

Paster N 1987 Effects of modified atmosphere on moulding and mycotoxin development BCPC Mono 37 Stored Products Pest Control pp 53-61

Paster N and L B Bullerman 1988 Mould spoilage and mycotoxin formation in grains as controlled by physical means International Journal of Microbiology 7 257-265

Phillips S R Mitfa and A Wallbridge 1989 Rice yellowing during drying delays J Stored Prod Res 25 155-164

Pitt J I and A D Hocking and D R Glenn 1983 An improved medium for the detection of *Aspergillus flavus* and *parasiticus* J Appl Bacteriol 54 109-114 pp

Pitt J I and A D Hocking 1997 Fungi and Food Spoilage Second Edition University Press Cambridge Great Britain

Quitco R 1983 Paddy deterioration from procurement to storage NAPHIRE Technical bulletin No 2 11pp

Richard Molard D B Diawara and B Cahagnier 1986 Susceptibility of cereal microflora to OXYGEN deficiency and carbon dioxide concentration Proc 4th International Working Conference on Stored Product Protection Tel Aviv Israel pp 85-92

Tolentino H A A P Dingle A C Rodriguez and A R Regpala 1992 Study on the alternatives to highway paddy drying in Central Luzon Philippines Unpublished Technical Report NAPHIRE Muñoz Nueva Ecija

Acknowledgements

The Principal and Principal Cooperating Investigators would like to thank the following officials and staff members of BPRE particularly Deputy Executive Director Jose B Santos Director Gloria Jimenez Planning and Evaluation Department Director Digna Monica Samaniego Finance and Administrative Department Director Ruben E Manalabe Postharvest Engineering Department Director Raquel Q Bermundo Mr Rolando L Tiongson Mrs Miriam A Acda and Mrs Perlina D Sayaboc Food Protection Department for their direct and indirect support given to this project We also appreciate the technical support of Mr Dionisio G Alvindia Mr Nelson C Santiago Mr Guillermo P Arguilles Ms Anna Marie F Bulanadi and Mrs Elsa A Ebue Finally we wish to express our gratitude to Mr T deBruin and staff of Haogenplast Ltd Israel for their support given to this project

Proceeedings of the 18th ASEAN seminar on grains postharvest technology Postharvest Technolog Towards Attaining Food Security" (Eds Irene Villapando, Carminia L Ramos, Bezt Gee A Salcedo Manila, Philippines, March 11-13 1997 pp 145-152

SESSION II B: PART I

Respiration Rates of Paddy at Different Temperatures and Moisture Contents

Jonathan E. Donahaye, David Chernoguz, Shlomo Navarro
Avi Azrieli and Miriam Rindner
Stored Products Department,
Agricultural Research Organization, Israel

Silvestre C. Andales
National Postharvest Institute for Research and Extension,
Muñoz, Nueva Ecija, Philippines

ABSTRACT

Laboratory experiments were undertaken to determine the effect of temperature and moisture content (MC) on respiration of paddy The experiments were carried out in glass jars (500 ml) filled with paddy, conditioned to five target levels of MC corresponding to the following water activities(a_W) 0 75, 0 80, 0 85 and 0 90, and held at 25, 30 and 35°C respectively The trials were carried out using low quality paddy (rain-damaged) with 23% germination, and high quality paddy with 91% germination A linear relationship was found between respiration rates expressed as log of oxygen consumption in mg O_2/100 g dry matter/day plotted against paddy MC For 18% MC at 35°C, respiration rate of high quality paddy was 20 361 mg O_2/100 g dry matter/day, and for 14% MC at 25°C it was 0 604 mg O_2/100 g dry matter/day For the same temperatures and MCs, the low quality paddy gave values of 17 175 and 0 585 mg O_2/100 g dry matter/day respectively

INTRODUCTION

In South-East Asia the harvesting of paddy in the monsoon season when sun drying is not feasible poses an acute problem In the Philippines, the NAPHIRE advocates two stage drying, whereby high moisture paddy should be dried down to below 18 percent moisture content (MC) in the first stage to minimize rapid deterioration, followed later by drying of intermediate moisture paddy down to below 14 percent (Andales, 1987) The maximum acceptable holding period for paddy at 18 percent MC, between the two drying stages is 21 days However, during this storage, weight losses due to respiration are inevitable Development of mycotoxins pose an additional risk if the temperature and humidity are suitable (Paster, 1987, Paster & Bullerman, 1989) and paddy quality may not be maintained over the imposed interim storage period until it is dried

Existing data in the literature on storage losses are not consistent. Steel *et al* (1969) determined the standard condition of temperature, MC and mechanical damage for calculation of safe storage time of corn up to 0 5 percent dry matter loss (DML) Seitz *et al* (1982) stated that high moisture, high mechanical damage and previous infestation can cause the development of dangerous quantities of microflora, especially *Aspergillus flavus*, even before reaching 0 5 percent DML in corn

This laboratory study was undertaken to examine the rates of respiration of paddy of intermediate moisture contents at different temperatures, and express these findings in terms of weight loss

MATERIALS AND METHODS

To determine the respiration rate of paddy, controlled laboratory experiments were undertaken by sealing paddy at five target levels of moisture content (MC) of 14, 15, 16, 17 and 18 percent, approximately corresponding to the following water activities, (a_w) 0 75, 0 80, 0 85, 0 88 and 0 90 The experiments were carried out at 25, 30 and 35°C

Preparation of paddy samples

IR-64, a widely planted rice variety in the Philippines, was used in the experiment. Two qualities of paddy were obtained. The first batch had been rain damaged and had an average initial germination level of 23 percent, while the second batch had an initial germination level of 91 percent. Both paddy consignments arrived from the Philippines at 13 1 percent MC Each batch was divided into five groups and these were then moistened to the five targeted MCs. This was done by adding to the paddy the amount of distilled water calculated to produce the required MC, using a hand-sprayer, followed by thorough mixing by rotation in 5 L plastic containers The containers were tightly closed with screw-lids and transferred to a refrigerator at 2 ± 1°C for conditioning Each container was rotated and shaken for 2 to 3 minutes daily After two weeks, the MC of each batch was checked twice a week by the oven method until readings became stable. If the MC after stabilization differed from the target MC by more than 0 2 percent, a further correction was made by adding a calculated amount of water, or by spreading the grain on a tray and drying Target MCs were reached after 2 to 4 weeks

Experimental procedure

Each batch of paddy at its target MC was placed in a 500-ml kilner-type glass jar with screw-on metal lid and gasket seal To enable gas sampling, a hole was drilled in the lid and fitted with a silicon-rubber septum. The exact volume of each jar was determined by filling with distilled water at 20°C Then, the jars were completely filled with grain to minimize headspace, and then weighed The void volume in the jars was calculated using the specific weight of paddy to subtract the volume of the paddy grains from the total jar volume. Before closing, the rims of the jars were spread with a fine layer of silicon grease to enhance sealing After the lid had been screwed down manually, it was tightened with a clamping tool, and each jar was tested for hermetic seal

After the jars had been sealed they were transferred to thermostatically-maintained chambers at the three experimental temperatures

Gas sampling

The rates of respiratory metabolism as expressed by O_2 uptake and CO_2 output were determined by removal of gas samples using a 1 ml gas-tight syringe, through the septum set in the lid of each jar Gas samples were analysed by chromatography on a Tracor MT - 565 gas chromatograph fitted with a thermal conductivity detector and a porapak Q column in series with a molecular sieve (13X) column The sampling port was equipped with a 0 25 ml sample injector loop The operating conditions were 50°C oven temperature, detector temperature of 70°C, column flow rate of 40 ml/min, and reference flow rate of 15 ml/min. Helium was the carrier gas and the analysis was computed by a Spectraphysics SP4100 integrator Concentrations were calculated on the basis of peak area. Peaks were calibrated using a standard gas mixture with known CO_2, O_2, and nitrogen (N_2) composition Sampling commenced immediately after sealing the flasks

and continued at 4, 6, 16 or 24 h intervals until the O_2 was consumed by the paddy, or for longer intervals for the lower MC paddy samples.

Data analysis

The O_2 and CO_2 concentrations were recorded regularly for each temperature and MC as described above. Based on a linear regression the rates of hourly O_2 consumption were determined. Then these values were converted to mg O_2 consumption per 24 h, using the void volumes in the jars and the dry weight of paddy

RESULTS AND DISCUSSION

The rates of O_2 consumption of the rain-damaged and good quality paddy at various moisture contents are given in Figs. 1 and 2 respectively The lines in the figures were plotted for the three temperatures used in the experiments.

For good quality paddy and at all three temperatures, there was an approximate doubling (x 1 7) in respiration rate for every 1 percent increase in MC over the tested range, and for rain-damaged paddy, this ratio was slightly higher (up to x 1 9) Similarly for every 5°C increase in temperature, the increase in respiration rate ranged from x 1 7 to x 2.2 for good quality paddy, and for rain-damaged paddy from x 1 5 to x 1 95

In this study, 14 percent MC was considered to be in equilibrium with 75 percnet r h. (Rindner *et al.*, 1991), which is the critical MC below which respiration rates are considerably inhibited. Results in Figs 1 and 2 show that at 14 percent MC, respiration rates at the three temperatures are very close to each other In contrast, for respiration rates obtained at higher MCs, the higher the temperature, the greater the difference.

These respiration rates may be used to calculate the daily dry matter loss derived from the joint activity of microfloral and paddy respiration using the equation for starch oxidation. Such calculations are needed to enable one to estimate the storability of grain, based on the frequently used criterion developed by Saul and Steele (1966) for maize in the US that a given percentage loss in dry matter, is economically acceptable. Subsequently, the 0 5 percent DML index for grade #2 maize was adopted by the USDA as a national standard. The times required to produce dry matter loss (DML) of 0 5 percent for the good quality paddy at the three experimental temperatures is given in Fig. 3 A number of previous studies has been made on DML of paddy[1], and a comparison of these results is given in Table 1

From the table it can be seen that the number of days to 0 5 percent DML estimated by Hilano (1982) were consistently shorter than what was found in this study (e.g. at 16% MC Hilano gave 50 days at 27°C as against 124 days at 25°C and 75 days at 30°C in this study). This was also true for the higher MCs in the studies of Chikubu (1970) and Jindel & Duggel (1978) In contrast, the times given by Teter (1982) and Esmay *et al* (1979) were consistently longer Data on rain-damaged paddy (Fig 2) would give longer DML periods, probably due to low seed viability The wide time range given in Table 1 and comparative results on rain damaged and good quality paddy suggest that additional data with other paddy quality parameters are needed for obtaining more reliable DML criteria for the safe storage of paddy

A comparison between the respiration of paddy and that of wheat may be made using the findings of Lacey *et al* (1997) who measured the respiration of wheat at different water activities (a_w) For wheat at 0 85 a_w, the respiration rate at 30°C was reported to be 22.167 mg/100g DM/ 24 h. For the same water activity, the MC of paddy was estimated to be 16 percent MC and the

respiration rate was 4 mg/100g DM/24 h at the same temperature

This shows that paddy respiration is far lower than wheat and the expected dry matter loss should be lower accordingly To obtain a 0 5 percent DML for wheat at 0 85 a_w and 35°C, the calculated time was only 21 days, in contrast to the 75 days for paddy at the same a_w and temperature as found in this study

The results obtained could also enable one to calculate O_2 consumption by paddy under sealed conditions Using the O_2 consumption results of this study, the time until O_2 is reduced to very low levels of about 2 percent can be calculated

The implications of the findings in this study lie in the widespread problem of handling moist paddy at harvest time In countries with a similar climate as the Philippines, paddy is usually harvested at 22 to 21percent MC during the dry season and 28 to 30 percent MC during the wet season (Mendoza *et al* 1984) More than half of the total annual volume of paddy-rice produced in the Philippines is harvested during the wet season (Philippine Agribusiness Fact Book and Directory 1991-1992) In a recently concluded survey, the purchase of wet paddy by rice traders in Bulacan and Nueva Ecija provinces is about 53 percent of the total volume produced during the wet season, and 13 percent of the total volume produced during the dry season (Tolentino *et al.,* 1992) This indicates the high volume of wet paddy handled during the rainy season

The use of mechanical dryers has, so far, been recognized as a method of preventing deterioration of wet paddy during the rainy season However, the high costs of investment maintenance, and operation are among the constraints limiting the adoption of this method especially in the rural areas (Bermundo & Quiambao, 1984 and Lorenzana 1985) To this day, sun drying continues to be the most favored method of drying Thus during the rainy season, farmers and traders alike are forced to wait for the sun to shine

The difficulty in adoption of mechanical dryers necessitates the examination of alternative solutions to prevent the fungal deterioration of wet paddy This study forms part of a more comprehensive approach to solving this problem

ACKNOWLEDGMENT

This work was carried out within the framework of CDR project C12-057 funded by USAID The authors thank Mr Rafael Dias for his technical assistance during this study

REFERENCES

Andales, S C 1987 Overview of Drying Technology in the Philippines ESCAP/RNAM Workshop on design of drying and milling equipment, Laguna Philippines Nov 1987

Bermundo, A.G , and R T Quiambao 1984 Socio-economic Study on the Utilization of Mechanical Grain Dryers NAPHIRE Technical Bulletin No 10, 20pp

Chikobu S 1970 Storage Condition and Storage Methods In Training in storage and preservation of food grains Asian Productivity Organization, Tokyo 109-136

Day, C L 1964 A Device for Measuring Voids in Porous Materials Agricultural Engineering, 36-37

Diawara B B Cahagnier, and D Richard-Molard 1986 Oxygen Consumption by a Wet Grain Ecosystem in Hermetic Silos at Various Water Activities pp 77-84 Eds E Donahaye and S Navarro, Proc 4th Int. Work. Conf Stored-Product Protection Tel Aviv Israel

34

Esmay M Soemangat Eryatno, and A. Phillips 1979 Rice Postproduction Technology in the Tropics University Press of Hawaii Honolulu 140 pp

Hilario M J 1982 Paddy Deterioration Indices In Paddy deterioration in the humid tropics Bagguio Philippines GTZ Publication, Eschborn, pp 191-194

Jindal V K. and A.K. Duggal 1978 Predicting the Safe Storage Period for Paddy with ContinuouS Aeration Proceedings Grain Post Harvest, Bankok, 260-275

Lacey J A. Hamer and N Magan 1997 Respiration of Wheat Grain Stored in Different Environments In Donahaye E. J, S Navarro and A, Varnava (eds) Proc Int. Conf Controlled Atmosphere and Fumigation in Stored Products, 21-26 April 1996 Printoco Ltd, Cyprus (in press)

Lorenzana J J 1985 Field Trials on the Performance of Selected Post-Harvest Facilities Installed in Village Farmers Associations in the Philippines Proc 8th ASEAN Technical Seminar on Grain Post Harvest Technology, Manila, Philippines pp 359-370

Mendoza M E., A.C Rigor R T Quitco and L.L. Ilag 1984 Grain Quality Deterioration in On-Farm Level of Operation NAPHIRE Technical Bulletin No 1 14pp

Paster N 1987 Effects of Modified Atmosphere on Moulding and Mycotoxin Development. BCPC Monograph No 37 Stored Products Pest Control, 53-61

Paster N and L B Bullerman 1989 Mould Spoilage and Mycotoxin Formation in Grains as Controlled by Physical Means International Journal of Microbiology, 7 257-265

Rindner Miriam E. Donahaye, S Navarro Y Blauschild and A. Azrieli 1991 Parameters for Apparaising the Storage Quality of Paddy Rice Hassadeh 71 1796-1797 (In Hebrew with English summary)

Saul R A., and J L. Steele 1966 Why Damaged Shelled Corn Costs More to Dry Agricultural Engineering 47 326-329, 337

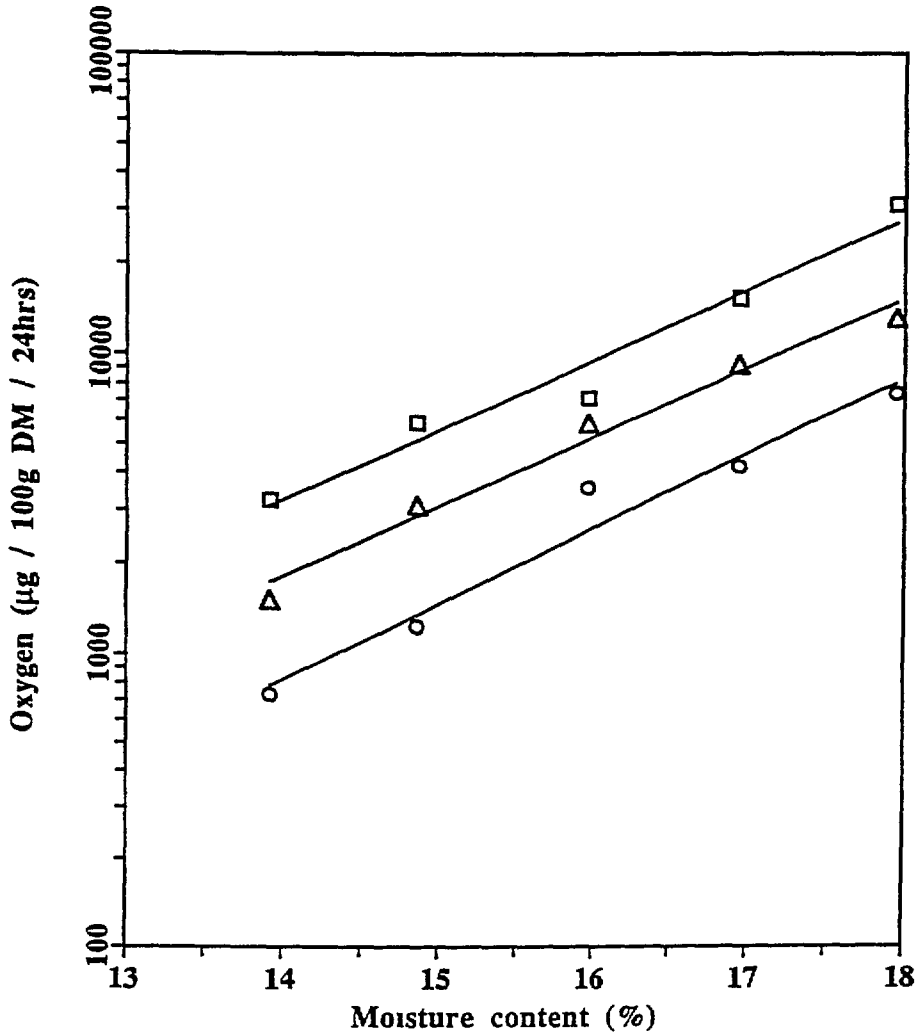
Seitz, L.M D B Sauer and H E. Mohr, 1982. Storage of High Moisture Corn Fungal Growth and Dry Meter Loss Cereal Chemistry 59 105-110

Steel, J L. R A. Saul, and W V Huckill, 1969 Deterioration of Shelled Corn as Measured by Carbon Dioxide Production Transactions of the ASAE, 12, 685-689

Teter N C 1982 Grain Storage South East Asia Cooperative Post Harvest Research and Development Program Manila 120pp

Tolentino H A. A.P Dingle, A.C Rodriguez and A.R Regpala, 1992. Study on the Alternatives to Highway Paddy Drying in Central Luzon, Philippines Unpublished Technical Report. NAPHIRE, Muñoz Nueva Ecija

35



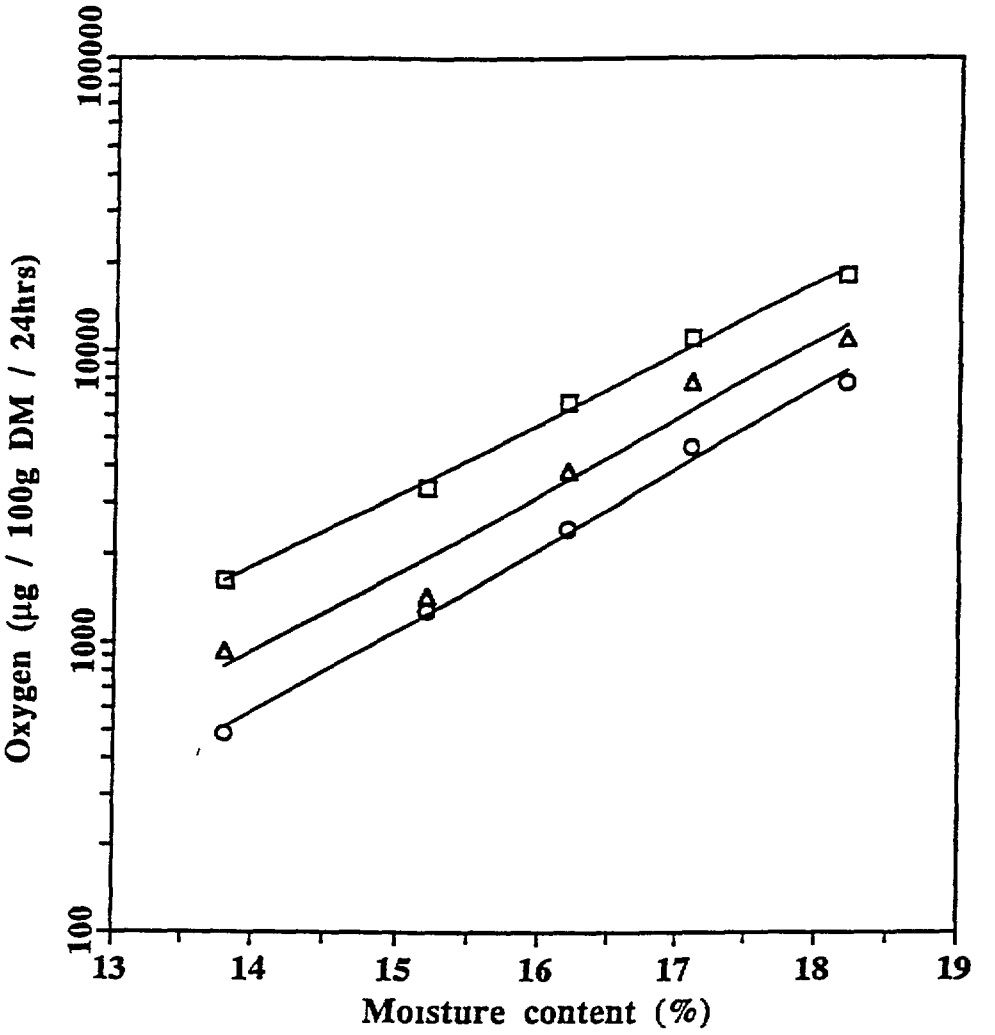
□ 35°C $y = 1.00173182 * 10^{0.23265710x}$ $r^2 = 0.981$

△ 30°C $y = 1.68726648 * 10^{0.23457559x}$ $r^2 = 0.963$

○ 25°C $y = 0.24791427 * 10^{0.25146213x}$ $r^2 = 0.962$

Figure 1 Rates of oxygen consumption of rain damaged paddy (23 percent germination) at various moisture contents and temperatures

36



□ 35°C $y = 0.71240390 * 10^{0.24345530x}$ $r^2 = 0.996$

△ 30°C $y = 0.17613655 * 10^{0.26602068x}$ $r^2 = 0.962$

○ 25°C $y = 0.07564398 * 10^{0.27750336x}$ $r^2 = 0.995$

Figure 2. Rates of oxygen consumption of good quality paddy (91 percent germination) at various moisture contents and temperatures

37

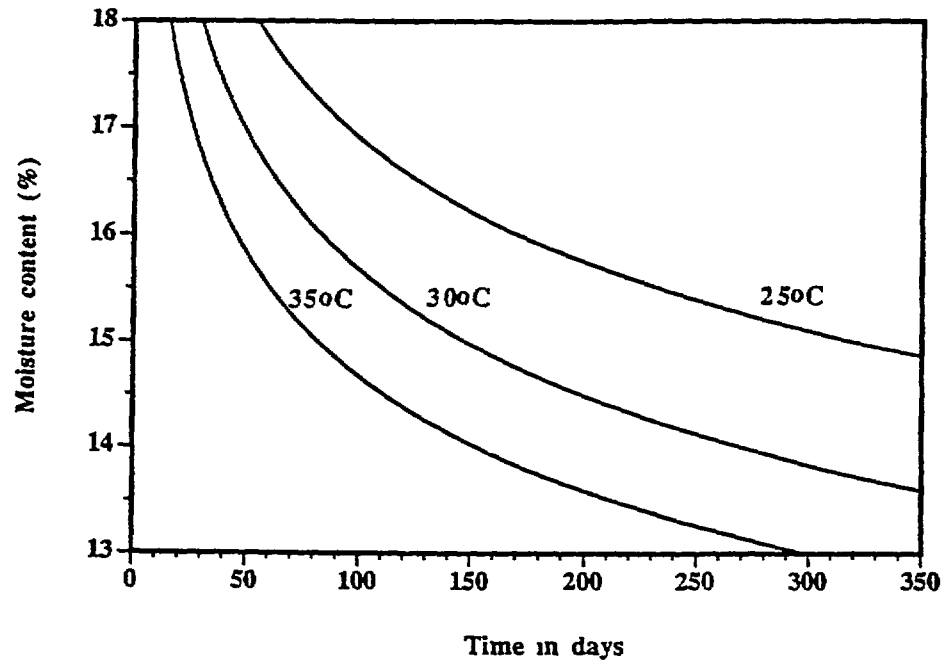


Figure 3 Effect of moisture content of paddy on safe storage time in days, based on time to reach 0 5 percent dry matter loss, at 25, 30 and 35°C

Table 1 Comparison of six studies on evaluation of times required for dry matter loss of paddy to reach 0 5%

	Present Results			Chikubu 1970	Jindel & Duggel	Teter (1982)	Hilario (1982)	Esmay et al (1979)
Temp °C	25	30	35	15-25	15-25	37 8	27	37 8
%MC								
12.0							3 300	2,300
13 0						1,020		
14 0	614	290	134			416	350	680
15 0	360	141	73			151		310
16 0	124	75	60			64	50	122
17 0	107	48	28	25-30	20	34		
18 0	60	33	14	15-20	13 6		25	47
19 0				15	10 4			
20 0				10	8 4		10	

38

Appendix 2 to Final report C12-057
FINAL CONTRACT REPORT

Sensory Qualities of Milled Raw and Cooked Rice from Paddy Stored with Different Moisture Contents and under Various Storage Durations

by

Angelita M del Mundo and Angelina dR Felix[1]

The study was conducted as a follow-up of a previous undertaking aimed at relating moisture content and storage duration of newly harvested paddy (IR64) to cooking and sensory qualities of the corresponding milled raw and cooked rice Samples evaluated had moisture contents of 14%, 15%, 16%, 17% and 18% Quality attributes from 0 day, 30 days, 60 days and 90 days were evaluated to establish periodic changes The same consumer panelists evaluated the sensory qualities from initial to final storage time Below are the specific objectives of the present study

1 To establish the optimum cooking water and document cooking parameters (height increase and cooking time) of milled IR64 stored as paddy at different moisture contents (14%, 15%, 16%, 17% and 18%) and storage periods (0 days, 30 days, 60 days and 90 days)
2 To compare the consumer acceptability and preference scores of milled raw and milled cooked IR64 stored as paddy at different moisture contents and durations
3 To identify quality changes in milled raw and milled cooked rice of experimental samples
4 To correlate various moisture contents and different storage time of IR64 paddy to cooking and sensory qualities of the corresponding milled raw and cooked rice samples

---

[1] Associate Professor and University Researcher respectively, Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, College, Laguna

Two kilos freshly milled IR64 stored as paddy under hermetic conditions at five moisture levels mentioned were received from the Bureau of Postharvest Research and Extension (BPRE) for four consecutive months IR64 stored at ambient temperature with an initial moisture content of 14% was also submitted with the experimental samples This sample served as the control

All samples were evaluated in terms of cooking parameters and sensory qualities based on the procedure of del Mundo (1991) Optimum cooking water was established for each sample upon receipt Cooking parameters measured include % height increase and cooking time Changes in the sensory qualities across moisture contents and storage durations were documented in both milled raw and milled cooked forms A consumer panel of 50 participants from Maitim, Bay, Laguna was employed This number allowed each treatment (14%, 15%, 16%, 17% and 18%) a replication of 30 times per session The same judges were employed during the four sessions that represent the different storage durations (0 day, 30 days, 60 days and 90 days) In each session, the participants were given a set of four cooked rice samples (three treatments and the control) The samples were assigned a three digit code number and presented to each judge based on the sample presentation plan according to the procedure of Cochran and Cox (1957) The warm cooked rice samples (10g) were placed in wine glasses covered with aluminum cover The four cooked samples were randomly arranged and were distributed to the judges in a tray together with a clear plastic spoon and a glass containing tap water Water was used as a rinse between evaluation of cooked rice samples to avoid carry over of quality characteristics perceived through the nasal and mouth cavities Four milled raw samples contained a miniature rice bin with individualized compartment were also presented to each of the judges Each compartment contained one teaspoon (7g) of the corresponding sample which was coded and arranged accordingly

The samples were evaluated in terms of the different milled raw and cooked characteristics After filling up the background information sheet, the scorecards for milled cooked then milled raw rice were distributed to the judges Description of each sample was given, acceptability indicated and best sample chosen by ranking the four samples registered by individual panelist

The mean of the replicated trial for the cooking parameters as % height increase and cooking time were computed for each sample Raw data on the sensory qualities were decoded and tabulated prior to data processing Acceptability was calculated by dividing the number of "yes" responses by the total number of responses and multiplying the dividend by 100 A percent acceptability of 75% and above is considered acceptable Meanwhile, preference score was expressed in scores of ranked data, following the procedure of Larmond (1985)

Preference score = (No of rank 1 x 1 03) + (No of rank of 2 x 0 30) + (No of rank 3 x -0 30) + (No of rank 4 x -1 03)

The total preference score obtained was divided by the number of judgments This was done to make values comparable between presentations and panel size A mean preference score of 1 03 was the highest attainable score However, a positive preference scores for a sample is generally accepted while a sample with negative score is generally rejected particularly when the difference in score is statistically significant compared with other samples

Cooking parameters data were subjected to analysis of variance using the F-test to determine treatment effects Duncan multiple range test (DMRT) was used to locate the significant differences Differences across moisture contents and storage durations in terms of the sensory qualities were on the other hand analyzed using the Kruskal-Wallis 1-Way ANOVA and the Friedman Two-Way ANOVA, respectively Correlation among the different cooking parameters and sensory attributes with moisture content and storage duration was established using the Spearman correlation analysis

The results of the cooking and sensory evaluations are as follows

1 Cooking parameters of milled IR64 stored as paddy at different moisture contents and storage durations

The optimum cooking water of experimental amount of milled rice from stored paddy samples of different moisture contents (14%, 15%, 16%, 17% and 18%) as well as that of the control during the initial and monthly intervals were the same Each 80g milled rice sample required 100mL (1 1 25) cooking water

Percent height increase which is used as an indicator of volume expansion ranged from 165 0% to 221 4% In general, an increasing trend in volume expansion was observed as paddy storage was prolonged On the other hand, a decreasing trend in percent height increase as moisture content increased from 14%, 15% to 16% was observed for the different storage periods For the samples of 17% and 18% moisture, no trend was recorded Moreover, no relationship was established between moisture content and % height increase (correlation coefficient = 0 15511)

Table 1 Percent height increase of milled cooked IR64 from paddy stored at different moisture contents and storage durations, 1998

Moisture Content	% Height Increase/Storage Time			
	0 day	30 days	60 days	90 days
Control/ Untreated Sample (14% RT)	173 4	173 0	196 4	206 8
Treated Samples - samples stored under hermetic condition at				
14% MC	179 0	189 9	205 2	205 4
15% MC	178 0	189 7	200 0	221 4
16% MC	165 0	182 0	190 3	196 6
17% MC	183 6	180 7	200 0	208 6
18% MC	166 1	182 3	181 0	185 0

Table 1a indicates slight variations but no trend between moisture content, storage period and cooking time Statistically, the differences in terms of cooking time across moisture contents and storage durations were not significant The mean cooking time of the samples ranged from 14 42 to 16 75 minutes The correlation coefficients of 0 00881 and 0 13462 were low to establish a relationship between cooking time and moisture content nor cooking time and storage duration, respectively

Table 1a Mean cooking time of milled cooked IR64 from paddy stored at different moisture contents and storage durations, 1998

Moisture Content	Mean Cooking Time (min)/Storage Time			
	0 day	30 days	60 days	90 days
Control/ Untreated Sample (14% RT)	15 25	15 27	14 94	14 42
Treated Samples - samples stored under hermetic condition at				
14% MC	15 13	16 70	15 25	15 47
15% MC	14 97	16 75	15 76	15 71
16% MC	14 75	16 10	14 87	14 79
17% MC	14 65	16 75	16 29	15 44
18% MC	15 25	15 27	14 94	14 42

2 Sensory qualities of milled cooked IR64 stored with different moisture contents for various durations

Results of the Spearman correlation analysis revealed that both moisture content and storage duration were found to be negatively correlated with all six (6) cooked rice attributes namely aroma, taste, tenderness, cohesiveness, color and gloss These characteristics became inferior at higher moisture level and longer storage period Among these attributes, aroma and flavor had the strongest negative correlation with moisture content and storage duration In fact, the poor acceptability and preference for samples of 16% MC to 18% MC in the cooked form was primarily dictated by the off odor (fermented smell) present in these samples In the raw form, wholeness of grains and color were found to have a significant negative correlation with moisture content and storage duration

Samples of higher moisture content had whiter shade of color and a higher proportion of whole grains compared to samples of higher moisture content As the length of paddy storage is increased and at a higher moisture content, color of the rice were towards the creamish to grayish shade and broken grains became more evident Correlation of this sensory result with the data obtained by BPRE using the Minolta Color Meter and with the % head rice recovery recorded during milling potentials determination, is suggested

Table 2 Relationship of paddy moisture contents and storage durations to sensory qualities of milled raw and cooked IR64, 1998

Parameters	Correlation Coefficient	
	Moisture Content	Storage Duration
A Milled Cooked Form		
% Acceptability	0 06063	0 06887
Preference Score	-0 15292 *	-0 04973
Aroma	-0 11187 *	-0 27206 *
Flavor	-0 08654 *	-0 16318 *
Tenderness	-0 06072	-0 14486 *
Cohesiveness	-0 08741 **	-0 17090 *
Color	-0 06801 **	-0 07723 **
Gloss	-0 09930 **	-0 04427
B Milled Raw Form		
% Acceptability	0 03081	0 02383
Preference Score	-0 10425 *	-0 00274
Aroma	-0 05509 ***	-0 04254
Color	-0 08556 *	-0 08831 *
Gloss	0 03212	0 03306
Wholeness of Grains	-0 09561 *	-0 10461 *
Brittleness of Grains	-0 00454	-0 01099
Grain Translucency	-0 04086	-0 05612

* - significant at 1% level of significance
** - significant at 5% level of significancce
*** - significant at 10% level of significance

Moreover, based on the results of the sensory evaluation (Appendix 1 to 7), the maximum paddy storage period for the following moisture contents recommend the following

- For 18% MC - one (1) month Perception of fermented smell (off odor) was very evident in cooked form during month 2 Other cooked qualities such as flavor, color and gloss as well as the raw qualities like color , wholeness of grains and translucency became inferior after one month of paddy storage
- 17% MC - one (1) month The same quality changes noted for sample of 18% moisture content
- 16% MC - can be extended to two (2) months Significant negative changes in cooked rice aroma as well as in such qualities as color and gloss in both cooked and raw forms were observed after two (2) months of paddy storage Other sensory qualities slightly changed after two(2) months of storage
- 15% MC - can be extended to three (3) months Slight change in sensory qualities Off odor slightly perceptible in cooked form after three (3) months of storage

14% MC - has shown remarkable sensory attributes even at three (3) months of paddy storage Still the recommended level for paddy storage In fact, paddy storage at 14% moisture level under hermetic condition may be extended even up to one (1) year Study by del Mundo (1994) showed that IR64 stored for one year at 12%-14% moisture under ordinary condition (room temperature) had comparable sensory qualities with that stored for three and six months

Appendix 1

Table 3 Percent acceptability of milled cooked IR64 stored as paddy at different moisture contents and storage durations, 1998

Moisture Content	% Acceptability/ Storage Time			
	0 day [ns]	30 days[ns]	60 days[**]	90 days[**]
MILLED COOKED				
Control/Untreated	98 0	96 0	96 0	94 0
Sample (14% RT) [ns]				
Treated Samples				
-samples stored				
under hermetic				
condition at				
14% MC [ns]	100 0	96 7	96 7	96 7
15% MC [**]	93 3	93 3	93 3	80 0
16% MC [**]	96 7	96 7	90 0	73 3
17% MC [**]	90 0	90 0	60 0	43 3
18% MC [**]	93 3	90 0	56 7	30 0

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Table 3a Percent acceptability of milled raw IR64 stored as paddy at different moisture contents and storage durations, 1998

Moisture Content	% Acceptability/ Storage Time			
	0 day [ns]	30 days[ns]	60 days[**]	90 days[**]
MILLED RAW				
Control/Untreated	96 0	100 0	96 0	96 0
Sample (14% RT) [ns]				
Treated Samples				
-samples stored				
under hermetic				
condition at				
14% MC [ns]	96 7	100 0	96 7	100 0
15% MC [ns]	90 0	96 7	93 3	93 3
16% MC [ns]	93 3	96 7	80 0	80 0
17% MC [ns]	93 3	93 3	80 0	70 0
18% MC [**]	86 7	86 7	76 7	63 3

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Appendix 2

Table 4 Mean preference scores of milled cooked IR64 stored as paddy at different moisture contents and storage durations, 1998

Moisture Content	Mean Preference Score/ Storage Time			
	0 day**	30 days**	60 days**	90 days**
MILLED COOKED				
Control/Untreated	0 06	0 42	0 34	0 37
Sample (14% RT)^{ns}				
Treated Samples				
-samples stored				
under hermetic				
condition at				
14% MC ^{ns}	0 49	0 51	0 51	0 68
15% MC ^{ns}	0 01	0 09	0 22	0 11
16% MC **	0 06	0 08	- 0 17	- 0 01
17% MC **	- 0 27	- 0 29	- 0 17	- 0 58
18% MC **	- 0 37	- 0 52	- 0 70	- 0 90

^{ns} - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Table 4a Mean preference scores of milled raw IR64 stored as paddy at different moisture contents and storage durations, 1998

Moisture Content	Mean Preference Score/ Storage Time			
	0 day**	30 days**	60 days**	90 days**
MILLED RAW				
Control/Untreated	0 38	0 42	0 31	0 47
Sample (14% RT)^{ns}				
Treated Samples				
-samples stored				
under hermetic				
condition at				
14% MC ^{ns}	0 51	0 49	0 48	0 79
15% MC ^{ns}	0 03	0 04	0 14	0 17
16% MC ^{ns}	-0 20	-0 04	- 0 01	- 0 21
17% MC ^{ns}	- 0 27	- 0 45	- 0 47	- 0 62
18% MC ^{ns}	-0 72	-0 77	-0 76	-0 86

^{ns} - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Appendix 3

Table 5 Mean aroma scores of milled cooked IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day**	30 days**	60 days**	90 days**
MILLED COOKED				
Control/ Untreated Sample (14% RT) ns	4 58	4 38	4 02	4 04
Treated Samples - samples stored under hermetic condition at				
14% MC ns	4 53	4 87	4 60	4 30
15% MC ns	4 47	4 43	4 30 (1)	3 33 (7)
16% MC	4 30	4 17	3 87 (4)	2 86 (9)
17% MC	4 10	4 23	2 30 (17)	1 77 (19)
18% MC	3 90	4 03	2 06 (19)	1 37 (26)

ns - no significant difference at 5% level of significance
- with significant difference at 5% level of significance
( ) - number of judges out of the 30 panelists who described the sample as having off odor

Table 5a Mean aroma scores of milled raw IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day ns	30 days**	60 days**	90 days**
MILLED RAW				
Control/ Untreated Sample (14% RT) ns	4 28	3 94	4 30	4 10
Treated Samples - samples stored under hermetic condition at				
14% MC ns	4 40	4 50	4 20	4 27
15% MC ns	4 20	4 03	4 00	4 17 (1)
16% MC ns	3 87	3 67	3 60 (3)	3 63 (3)
17% MC ns	3 97	3 93	3 63 (4)	2 80 (10)
18% MC ns	3 53	3 83	3 20 (8)	3 00 (8)

ns - no significant difference at 5% level of significance
- with significant difference at 5% level of significance
( ) number of judges out of the 30 panelists who described the sample as having off odor

Numerical Score	Equiv Aroma Description
1	With off odor
2	No aroma
3	Weak aroma
4	Moderately aromatic
5	Aromatic

Appendix 4

Table 6 Mean flavor scores of milled cooked IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[ns]	30 days[ns]	60 days[**]	90 days[**]
Control/ Untreated Sample (14% RT)[ns]	4 38	4 30	4 58	4 18
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	4 17	4 43	4 20	4 33
15% MC [ns]	4 30	4 38	4 33	3 90 (1)
16% MC [ns]	4 17	3 83	3 87	3 70 (2)
17% MC	4 17	3 87	3 90	2 97 (3)
18% MC	4 17	3 83	3 33	2 44 (10)

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance
( ) - number of judges out of the 30 panelist who described the samples to have off taste

Numerical Score	Equiv Flavor Description
1	With off taste
2	Bland
3	Weak taste
4	Moderately tasty
5	Tasty
6	Very tasty

Appendix 5

Table 7 Mean tenderness scores of milled cooked IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[ns]	30 days[ns]	60 days[**]	90 days[**]
Control/ Untreated Sample (14% RT)[ns]	2 90	2 74	2 70	2 84
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	3 27	3 20	3 00	3 17
15% MC [ns]	2 90	2 77	3 00	2 90
16% MC [ns]	2 80	2 67	2 50	2 80
17% MC [ns]	2 73	2 73	2 30	2 33
18% MC [ns]	2 67	2 83	2 40	2 33

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Table 8 Mean cohesiveness scores of milled cooked IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[ns]	30 days[ns]	60 days[ns]	90 days[ns]
Control/ Untreated Sample (14% RT)[ns]	3 44	3 20	3 20	3 24
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	3 67	3 40	3 47	3 10
15% MC [ns]	3 47	3 17	3 10	2 93
16% MC [ns]	3 47	2 97	3 20	3 28
17% MC [ns]	3 27	2 80	2 52	2 60
18% MC [ns]	3 10	3 23	2 90	3 34

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Numeral Value	Tenderness Description	Cohesiveness Description
1	Tough	Well separated
2	Chewy	Separated
3	Moderately Tender	Moderately sticky
4	Tender	Sticky

Appendix 6

Table 9 Mean color scores of milled cooked IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[ns]	30 days[**]	60 days[**]	90 days[**]
MILLED COOKED				
Control/ Untreated Sample (14% RT)[ns]	4 56	4 36	4 28	4 46
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	4 50	4 78	4 53	4 50
15% MC [ns]	4 53	4 37	4 23	4 13
16% MC	4 63	4 27	4 50	4 27
17% MC	4 47	4 37	4 07	3 60
18% MC	4 20	3 90	3 57	3 33

[ns] no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Table 9a Mean color scores of milled raw IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[**]	30 days[**]	60 days[**]	90 days[**]
MILLED RAW				
Control/ Untreated Sample (14% RT)[ns]	4 54	4 38	4 42	4 28
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	4 53	4 43	4 57	4 57
15% MC [ns]	4 50	4 30	4 37	4 27
16% MC [ns]	3 93	4 00	3 90	4 20
17% MC	4 20	3 77	3 40	3 40
18% MC [*]	3 57	3 90	3 37	3 17

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Numeral Value	Color Description
1	Blackish white
2	Grayish white
3	Yellowish
4	Creamish white
5	White

Appendix 7

Table 10 Mean gloss scores of milled cooked IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[ns]	30 days[ns]	60 days[ns]	90 days[**]
MILLED COOKED				
Control/ Untreated Sample (14% RT)[ns]	3 34	3 10	2 92	3 02
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	3 07	3 53	3 23	3 20
15% MC [ns]	3 20	3 03	3 07	2 77
16% MC	3 37	3 33	2 70	3 30
17% MC	3 13	2 97	2 50	2 40
18% MC	3 20	2 87	2 57	2 00

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Table 10a Mean gloss scores of milled raw IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day[**]	30 days[**]	60 days[**]	90 days[**]
MILLED RAW				
Control/ Untreated Sample (14% RT)[ns]	3 52	3 56	3 55	3 58
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	3 12	3 23	3 57	3 57
15% MC [ns]	2 77	3 10	3 43	2 93
16% MC [ns]	2 63	2 97	2 77	2 90
17% MC [ns]	2 67	2 33	2 37	2 07
18% MC [ns]	2 07	2 83	2 47	2 24

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Numeral Value	Gloss Description
1	Very dull
2	Dull
3	Moderately glossy
4	Glossy
5	Very glossy

Appendix 8

Table 11 Mean wholeness of grains scores of milled raw IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day**	30 days**	60 days**	90 days**
Control/ Untreated Sample (14% RT) ns	4 58	4 64	4 44	4 40
Treated Samples - samples stored under hermetic condition at				
14% MC ns	4 43	4 27	4 30	4 27
15% MC ns	3 76	3 83	3 63	3 60
16% MC ns	3 80	3 63	3 43	3 57
17% MC ns	3 62	3 83	3 33	3 33
18% MC ns	3 39	3 17	2 93	2 93

ns - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Numerical Score	Equiv Wholeness of Grains Description
1	Grits
2	Broken
3	Predominantly broken
4	Predominantly whole grain
5	Whole grains

Appendix 9

Table 12 Mean grain translucency scores of milled raw IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day**	30 days**	60 days**	90 days**
Control/ Untreated Sample (14% RT) ns	3 42	3 56	3 46	3 34
Treated Samples - samples stored under hermetic condition at				
14% MC ns	3 50	3 47	3 47	3 47
15% MC ns	3 20	3 23	3 13	3 10
16% MC ns	3 10	3 20	2 97	2 87
17% MC	3 23	2 93	2 67	2 83
18% MC **	2 23	2 43	2 33	2 17

ns - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Numerical Score	Equiv Grain Translucency Description
2	Opaque
3	Chalky
4	Moderately chalky
5	Translucent

Appendix 10

Table 13 Mean brittleness of grains scores of milled raw IR64 stored as paddy at various moisture contents and length of storage, 1998

Moisture Content	Mean Value/ Storage Time			
	0 day**	30 days**	60 days**	90 days**
Control/ Untreated Sample (14% RT)[ns]	4 68	4 64	4 62	4 72
Treated Samples - samples stored under hermetic condition at				
14% MC [ns]	4 70	4 43	4 73	4 70
15% MC [ns]	4 57	4 47	4 37	4 43
16% MC [ns]	4 30	4 23	4 23	4 41
17% MC [ns]	4 17	4 17	4 20	4 11
18% MC [ns]	4 10	4 17	3 93	3 96

[ns] - no significant difference at 5% level of significance
- with significant difference at 5% level of significance

Numerical Score	Equiv Brittleness of Grains Description
3	Soft
4	Soft but yielding ("makunat")
5	Brittle

APPENDIX 3 to Final Report C-12 057

FINAL CONTRACT REPORT

Sensory Qualities of Milled Raw and Cooked Rices from Wet Paddy Stored in a Volcani Cube

by

Angelita M del Mundo and Angelina dR Felix[1]

The undertaking was conducted as an offshoot of the study on the cooking and sensory qualities of milled raw and cooked rices from hermetically stored paddy at different moisture contents and storage durations under a laboratory set-up The present study aimed to evaluate the efficiency of a Volcani cube set-up as a storage structure for wet paddy The study consisted of two activities

Activity 1 *Comparative cooking and sensory qualities of milled raw and cooked rice from wet paddy (18% moisture content) stored in a Volcani cube and under conventional storage set-up*

Activity 2 *Cooking and sensory qualities of milled cooked and raw rice of wet paddy stored in two piles with various layers under a Volcani cube set-up*

The contract was implemented for the period November 15, 1997 to August 30, 1998 Samples evaluated were supplied in the milled form by the Bureau of Postharvest Research and Extension (BPRE) For activity 1, the rice used consisted of 1) IR64 of 14% moisture content stored in a conventional set-up, 2) IR64 of 18% moisture content stored in a conventional set-up, and 3) IR64 of 18% moisture content stored in a Volcani cube set-up These samples were received for three consecutive times representing a tri-monthly periods (initial time, after three months of storage and after six months of storage) Milled rice came from a composite of paddy samples stored in each of the three set-ups based on the sampling design of BPRE

The Volcani cube set-up was prepared by placing the wet paddy samples in polypropylene bags of 50 kilos each and hermetically storing them in a Volcani cube The Volcani cube was set-up in an open area and was covered with an aluminet Two Volcani cube set-up labeled as pile 1 and pile 2 were prepared Pile 1 was opened after three months and pile 2 after six months Each pile has seven layers The sample for sensory evaluation was obtained as a composite of the paddy in the middle or 4th layer of the pile

Adjacent to the Volcani cube set-up were two conventional storage set-ups, one for 14% moisture and another for the 18% moisture level Samples for the conventional storage set-up were contained in polypropylene bags, stacked in pallets and covered with flat tarpaulin sheets Three kilos paddy samples were randomly obtained from the different sides of each of the conventional set-ups for the two storage periods

In activity 2, seven milled rice samples from the seven layers of the Volcani cube set-up were received during month 3 and month 6 for quality evaluation The samples were received one week after receipt of the samples for activity 1

---

[1] Associate Professor and University Researcher respectively, Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Baños, College, Laguna

Two piles of Volcani cube were set-up for activity 2 These piles were located near the set-ups for activity 1 in the BPRE compound in Muñoz, Nueva Ecija Pile 1 was opened during the third month and pile 2 during the sixth month Each pile consisted of seven layers with the topmost layer numbered as level 1 and the bottom layer as level 7 There were twenty two to thirty one (22 to 31) polypropylene bags of wet paddy (18% moisture) in each layer Three kilos of composite paddy samples from each layer per pile were obtained, dried to 14% and milled Out of the three kilos composite paddy, two kilos of milled rice were received for evaluation of cooking parameters and sensory qualities for the two storage periods under study

All samples for activities 1 and 2 underwent a complete evaluation for cooking parameters Similarly, all samples in the milled raw form were assessed sensorically However, for the milled cooked form, only those stored for three months were subjected to sensory evaluation The strong unacceptable fermented odor during the determination of the cooking parameters of the samples from the six months storage pile led to the suspension of their sensory evaluation

Cooking and sensory assessments were conducted based on the procedure of del Mundo as stated in the previous contract report using the samples from the laboratory set-up

Two sets of consumer panel were employed in this undertaking The first group were farmers, housewives and out-of-school youths from Maitim, Bay, Laguna The second group consisted of researchers, administrative staff and field laborers from UPLB and PhilRice Los Baños UPLB students were also included in the second group All the participants in both areas had experience in rice sensory evaluation

The experimental samples were replicated 30 times As such, 30 and 56 participants in each area were employed as panelists for activity 1 and activity 2, respectively The same groups of consumer panelists were employed to evaluate the samples from the various storage periods

The results of the evaluation are as follows

<u>Activity 1</u> *Comparative cooking and sensory qualities of wet paddy(18% moisture content) stored in a Volcani cube set-up and under conventional storage set-up*

- The optimum cooking water for the experimental amount of milled rice from wet paddy (18% moisture content) stored in a Volcani cube set-up and under conventional set-up during the initial and two storage periods was the same The sample of 14% moisture content stored under the conventional set-up likewise have the same optimum cooking water Each 80g milled rice sample required 100mL (1 1 25) cooking water

- There was no significant difference in percent height increase (used as an indicator of volume expansion) among samples during each storage period Percent height increase ranged from 146 9% to 221 4% Meanwhile, cooking time ranged from 15 4 to 18 4 minutes A generally increasing but insignificant trend in cooking time was noted as paddy storage is prolonged

Table 1 Percent height increase of milled cooked IR64 from paddy stored in two set-ups for various storage periods, 1998

Set-up/Samples	% Height Increase/Storage Time		
	Initial Time (0 month)	Three (3) Months	Six (6) Months
Samples Stored Under Conventional Set-up			
- 14 % MC	173 0	221 4	213 3
- 18 % MC	163 5	208 5	201 7
Sample (18% MC) Stored in a Volcani Cube			
- pile 1	182 5	199 2	-
- pile 2	146 9	-	195 2

- no evaluation as per BPRE sampling design

Table 2 Cooking time of milled cooked IR64 from paddy stored in two set-ups for various storage periods, 1998

Set-up/Samples	Cooking Time (min)/Storage Time		
	Initial Time (0 month)	Three (3) Months	Six (6) Months
Samples Stored Under Conventional Set up			
- 14 % MC	16 0	17 5	18 2
- 18 % MC	15 4	16 9	18 0
Sample (18% MC) Stored in a Volcani Cube			
- pile 1	17 0	17 0	-
- pile 2	16 0	-	18 4

- no evaluation as per BPRE sampling design

- Tables 3-13 present the results of the sensory evaluation The milled cooked and raw rice qualities of the samples with 14% and 18% moisture contents stored under the conventional set-up and the sample (18% moisture) stored in a Volcani cube set-up were comparable during the initial time After three months of wet paddy storage, the tenderness and cohesiveness of the milled cooked rices from the different set-ups remained comparable There was also no significant differences in such milled raw rice qualities as wholeness of grains, grain translucency and grain brittleness across storage set-ups and durations Sample from the Volcani cube set-up however became inferior in terms of the other characteritics after storage There was a decrease in the overall rating for cooked rice flavor, color and gloss from initial time to third month of paddy storage Similarly, the rating for milled raw rice color and gloss consistently decline after three and six months of paddy storage in a Volcani cube set-up The characteristics which were highly affected by wet paddy storage in a Volcani cube set-up were the aroma, percent acceptability and preference scores of the milled cooked and raw rice samples

1 **Aroma** The aroma of the sample stored in a Volcani cube set-up was significantly inferior from samples stored under the conventional set-up Off odor specifically a fermented smell was perceptible in both milled cooked and raw rices from wet paddy stored for three

months Eighteen judges from UPLB and 19 from Bay had indicated this off odor in the cooked form Moreover, 21 and 15 judges from the two areas respectively had noted the fermented smell in the raw form After six months of paddy storage, the milled cooked form of the samples from the Volcani cube set-up were no longer presented for sensory evaluation due to a highly distinct fermented smell recorded during the cooking trials In the raw form, the off odor of the sample stored as wet paddy in a Volcani cube set-up for six months was noted by 28 and 24 out of the 30 judges from UPLB and Bay, respectively

2 **Acceptability** A 35 0% and 51 6% mean acceptability from the two sensory sites was recorded in the cooked and raw samples from a Volcani cube set-up of three months storage These percentages were significantly lower compared to the percent acceptability of the samples stored under conventional set-up The sample of 14% moisture had a mean acceptability of 95% in the cooked form and 91 7% in the raw form The sample of 18% moisture stored under conventional set-up had a mean acceptability of 90 0% and 84 7% in milled cooked and raw forms, respectively After six months of paddy storage, only two judges from Bay and one from UPLB had indicated acceptability for the raw sample from wet paddy stored in a Volcani cube set-up

3 **Preference** Sample from the Volcani cube set-up received a consistent negative score in the milled cooked form compared to the samples stored under the conventional set-up The difference in preference score of the milled cooked sample across storage set-ups was significantly wider for the third month storage than for the initial time Similarly, there was a notable decrease in preference score of milled raw rice from wet paddy stored in a Volcani cube set-up from initial time to three months and to six months of storage

- Meanwhile, between the two moisture levels (14% and 18%) stored under conventional set-up, samples were found to be generally comparable in terms of the different milled cooked and raw rice qualities In terms of the overall acceptability and preference scores, sample of 14% moisture content was better than the sample of 18% moisture after three and six months of paddy storage

Table 3 Percent acceptability of milled cooked IR64 stored at 14% and 18% moisture contents for various storage periods, 1998

Set-up/Samples	% Acceptability/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set-up						
14% MC	96 7	90 0	90 0	100 0	90 0	90 0
18% MC	100 0	93 3	80 0	83 3	73 3	83 3
Sample (18% MC) in Volcani cube set-up						
- pile 1	96 7	90 0	23 3	46 7	-	-
- pile 2	100 0	90 0	-	-	**	**

- no evaluation as per BPRE sampling design
** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Table 3a Percent acceptability of milled raw IR64 stored at 14% and 18% moisture contents for various storage periods, 1998

Set-up/Samples	% Acceptability/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set up						
- 14% MC	100 0	90 0	90 0	93 3	80 0	90 0
- 18% MC	93 3	86 7	86 7	83 3	53 3	90 0
Sample (18% MC) in Volcani cube set-up						
- pile 1	100 0	100 0	43 3	60 0	-	-
pile 2	96 7	93 3	-	-	3 3	6 7

- no evaluation as per BPRE sampling design

Table 4 Mean preference of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set up/Samples	Mean Preference Score/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set up						
14% MC	0 07	0 09	0 51	0 51	0 11	0 06
18% MC	0 16	0 18	0 28	0 06	-0 11	-0 06
Sample (18% MC) in Volcani cube set-up						
- pile 1	-0 25	-0 14	-0 79	-0 44	-	-
pile 2	-0 18	-0 12	-	-	**	**

- no evaluation as per BPRE sampling design

** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Table 4a Mean preference score of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Preference Score/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set up						
- 14% MC	0 06	-0 13	0 51	0 55	0 57	0 40
- 18% MC	0 23	0 11	0 11	-0 18	0 20	0 31
Sample (18% MC) in Volcani cube set-up						
pile 1	0 44	0 34	-0 62	0 36	-	
pile 2	-0 05	-0 45	-		-0 79	-0 71

- no evaluation as per BPRE sampling design

Table 5 Mean aroma scores of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set up						
14% MC	4 0	4 4	3 5	4 2	3 6	4 0
18% MC	4 0	4 5	3 3	3 6	3 2	4 0
Sample (18% MC) in Volcani cube set up						
pile 1	4 0	4 0	1 5	2 0	-	-
pile 2	4 0	4 0	-	-	**	**

- no evaluation as per BPRE sampling desing

** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Table 5a Mean aroma scores of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 Month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set-up						
- 14% MC	3 5	3 8	2 9	4 0	3 0	2 8
- 18% MC	3 4	4 0	2 9	3 0	1 9	2 7
Sample (18% MC) in Volcani cube set-up						
- pile 1	3 5	4 0	1 6	2 2	-	-
- pile 2	3 6	4 0		-	1 1	1 3

- no evaluation as per BPRE sampling design

Numerical Score	Equiv Aroma Description
1	With off odor
2	No aroma
3	Weak aroma
4	Moderately aromatic

Table 6 Mean color scores of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set up						
- 14% MC	4 6	4 7	4 1	4 7	4 4	4 5
- 18% MC	4 6	4 4	3 9	4 0	4 0	4 0
Sample (18% MC) in Volcani cube set-up						
- pile 1	4 5	4 2	4 0	4 0	-	
- pile 2	4 5	4 5	-	-	**	**

- no evaluation as per BPRE sampling design

** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Table 6a Mean color scores of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 Month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set up						
- 14% MC	4 3	4 0	4 5	4 9	4 2	4 0
18% MC	4 2	4 5	3 9	3 4	3 2	3 6
Sample (18% MC) in Volcani cube set-up						
- pile 1	4 6	4 4	4 1	3 6	-	-
- pile 2	4 0	4 0	-	-	2 9	3 0

- no evaluation as per BPRE sampling design

Numeral Value	Color Description
1	Blackish white
2	Grayish white
3	Yellowish
4	Creamish white
5	White

Table 7 Mean gloss scores of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set up						
- 14% MC	3 5	3 4	2 8	2 5	2 4	2 9
18% MC	3 5	3 1	2 8	2 6	2 3	3 4
Sample (18% MC) in Volcani cube set up						
- pile 1	3 0	3 0	2 3	2 4	-	-
- pile 2	3 2	3 3	-	-	**	**

- no evaluation as per BPRE sampling design
** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

62

Table 7a Mean gloss scores of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 Month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set-up						
- 14% MC	2 5	3 0	2 5	3 3	2 1	2 6
- 18% MC	2 4	3 0	2 3	2 3	1 9	2 3
Sample (18% MC) in Volcani cube set-up						
pile 1	2 3	2 7	2 1	2 3	-	
pile 2	2 3	3 0	-		1 5	1 5

- no evaluation as per BPRE sampling design

Numeral Value	Gloss Description
1	Very dull
2	Dull
3	Moderately glossy
4	Glossy
5	Very glossy

Table 8 Mean flavor scores of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set up						
- 14% MC	4 4	4 3	4 3	4 4	3 9	4 1
- 18% MC	4 4	4 6	3 8	4 2	3 7	3 9
Sample (18% MC) in Volcani cube set-up						
pile 1	4 2	4 0	2 3	3 1	-	-
pile 2	4 2	4 2	-	-	**	**

- no evaluation as per BPRE sampling design
** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Numerical Score	Equiv Flavor Description
1	With off taste
2	Bland
3	Weak taste
4	Moderately tasty
5	Tasty

Table 9 Mean tenderness scores of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set up						
- 14% MC	2 8	3 0	2 8	2 6	2 5	2 3
- 18% MC	2 7	3 2	2 6	2 5	2 6	2 4
Sample (18% MC) in Volcani cube set up						
pile 1	2 7	2 8	2 4	2 5	-	-
pile 2	3 3	2 6	-	-	**	**

- no evaluation as per BPRE sampling design
** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Table 10 Mean cohesiveness scores of milled cooked IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED COOKED						
Samples Stored Under Conventional Set-up						
14% MC	3 7	3 0	3 3	3 5	2 9	3 4
18% MC	3 7	3 4	3 4	3 4	3 2	3 3
Sample (18% MC) in Volcani cube set up						
- pile 1	3 2	3 2	2 9	2 9	-	-
- pile 2	3 7	3 2	-	-	**	**

- no evaluation as BPRE sampling design
** not evaluated due to a very strong fermented smell (off odor) established during cooking trials

Numeral Value	Tenderness Description	Cohesiveness Description
1	Tough	Well separated
2	Chewy	Separated
3	Moderately Tender	Moderately sticky
4	Tender	Sticky

Table 11 Mean wholeness of grains scores of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/ Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 Month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set-up						
- 14% MC	4 2	4 2	4 2	4 3	4 4	4 4
- 18% MC	4 0	3 8	4 0	4 2	4 3	4 0
Sample (18% MC) in Volcani cube set-up						
pile 1	4 4	4 5	4 2	3 8	-	
pile 2	4 1	4 0	-	-	4 0	4 0

- no evaluation as per BPRE sampling design

Numerical Score	Equiv Wholeness of Grains Description
1	Grits
2	Broken
3	Predominantly broken
4	Predominantly whole grain
5	Whole grains

Table 12 Mean brittleness of grains scores of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 Month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set-up						
14% MC	4 3	4 0	4 8	4 7	4 8	4 5
18% MC	4 3	4 0	4 5	4 4	4 5	4 0
Sample (18% MC) in Volcani cube set-up						
pile 1	4 6	4 2	4 5	4 4	-	-
pile 2	4 5	4 3	-	-	4 5	4 3

- no evaluation as per BPRE sampling design

Numerical Score	Equiv Brittleness of Grains Description
3	Soft
4	Soft but yielding ("makunat")
5	Brittle

Table 13 Mean grain translucency scores of milled raw IR64 stored in two set-ups for various storage periods, 1998

Set-up/Samples	Mean Value/ Storage Period/ Area					
	Initial Time (0 Month)		Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY	UPLB	BAY
MILLED RAW						
Samples Stored Under Conventional Set-up						
- 14% MC	3 2	3 0	3 5	3 4	3 4	3 3
- 18% MC	3 3	3 5	3 0	2 8	3 1	3 0
Sample (18% MC) in Volcani cube set-up						
pile 1	3 4	3 4	3 0	3 0	-	-
pile 2	3 2	2 5	-	-	2 7	2 3

- no evaluation as per BPRE sampling design

Numerical Score	Equiv Grain Translucency Description
2	Opaque
3	Chalky
4	Moderately chalky
5	Translucent

Activity 2 *Cooking and sensory qualities of milled cooked and raw rices of wet paddy stored in two piles with seven layers in a Volcani cube set-up*

- Optimum cooking water was the same for the seven samples during the two storage periods A rice water ratio of 1 1 25 (100mL water per 80g milled rice) was established for all samples during the third and sixth months of wet paddy storage

- Percent height increase and cooking time were comparable across samples during each storage periods There was however a diminishing trend in height increase and an increasing trend in cooking time as wet paddy storage is extended from three months to six months Height increase ranged from 179 7% to 203 3% for samples of three months of storage and from 157 4% to 194 8% for sample of six months of storage Cooking time was from 16 0 to 18 0 minutes and from 17 4 to 19 0 minutes during month 3 and month 6, respectively

- A difference in acceptability scores was registered by the two sets of consumer panelists Consumer panelists from UPLB were generally more choosy compared to the those from Maitim, Bay, Laguna particularly in terms of milled cooked rice quality The samples from all layers of the Volcani cube set-up were rated as unacceptable by the consumer panelists from UPLB Meanwhile, panelists from Bay, Laguna accepted the cooked form of paddy stored in the Volcani cube set-up except those stored in the first two topmost layers (layers 1 and 2) In the milled raw form, both sets of consumer panelists indicated acceptability for samples coming from layers 3, 4 and 7 during the third month Both sets of panelists also rated the milled raw samples from all Volcani cube layers as unacceptable during the sixth month Despite the negative similarity in ratings across sets of consumer panelists, the acceptability rating given by panelists from Maitim, Bay, Laguna was higher than the rating indicated by UPLB panelists

- Preference score indicates choice The consumer panelists were requested to rank the samples to indicate preference Panelists in UPLB as well as in Bay, unanimously rated the samples from layer 1 and layer 2 as the worst among the samples from the seven layers The rating was both for milled cooked and milled raw forms from month 3 storage The rice sample from layer 7 was rated as the best sample in both milled cooked and raw forms After six months of paddy storage, the samples were no longer presented for sensory evaluation in the cooked form The samples had distinct off odor and the laboratory staff already refused to taste the samples presented to them during the optimum cooking water determination Only the milled raw rices from the seven layers were presented to the panelists and all were rated unacceptable However, if the panelists have to make a choice from among the seven unacceptable samples, they indicated higher scores for samples coming from layers 4 to 7

- The major drawback of the samples from top layers during month 3 as well as all samples during month 6 was their off odor/fermented smell During month 3, fermented smell was distinct in samples coming from layers 1 and 2 Off odor of lesser intensity was noted for all other samples Between cooked and raw rice forms, the intensity of the fermented smell was stronger in cooked form After six (6) months of paddy storage, the off odor/fermented smell became highly perceptible in all samples including those in the raw form

- A slight variation across samples in terms of raw rice characteristics like color, gloss, wholeness of grains, brittleness of grains and grain translucency were noted during month 3 Similarly, for month 6 samples, there was an insignificant decrease in overall rating in terms of the raw rice characteristics such as gloss, wholeness of grains, brittleness of grains and grain translucency Color of the raw rice grains however notably changed from creamish white to yellowish after six months of paddy storage for samples coming from layers 3 to 7 The yellowish color of the samples from layers 1 and 2 during month 3 were further intensified during month 6

- Among the samples from the seven (7) layers in the Volcani cube set-up, scores and descriptions for the various sensory attributes were higher and/or better for samples in the lower layers

- Sample from the lowest layer of stored wet paddy in a Volcani cube set-up for three months can still be acceptable in both cooked and raw forms to consumers from a rice farming community such as Maitim, Bay, Laguna However, regardless of layer, a duration of six (6) months is inappropiate for wet paddy storage

Table 14 Mean percent height increase of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layer	% Height Increase /Storage Period	
	Three (3) Months	Six (6) Months
1	203 3	194 8
2	186 7	157 4
3	193 3	186 9
4	190 0	186 9
5	179 0	177 8
6	186 9	182 8
7	179 7	165 6

Table 15 Mean cooking time of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Cooking Time (mins) /Storage Period	
	Three (3) Months	Six (6) Months
1	18 0	18 8
2	16 7	17 4
3	17 8	17 7
4	18 9	18 8
5	16 0	17 8
6	16 3	18 2
7	18 6	19 0

Table 16 Percent acceptability of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	% Acceptability/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	18 8	28 1		
2	28 1	46 9		
3	50 0	75 0	no sensory evaluation	
4	53 1	81 2	due to strong fermeneted	
5	50 0	81 2	odor established during	
6	46 9	84 4	cooking trials	
7	56 3	84 4		

Table 16a Percent acceptability of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	% Acceptability/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	37 5	40 6	0 0	21 9
2	21 9	46 9	9 4	15 6
3	81 2	81 2	9 4	15 6
4	78 1	84 4	15 6	33 3
5	46 9	68 8	21 9	34 4
6	39 1	68 8	25 0	35 5
7	90 6	96 8	21 9	31 2

Table 17 Mean preference score of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Preference Score/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	-0 69	-0 61		
2	-0 35	-0 28	no sensory evaluation	
3	0 19	0 21	due to strong fermented	
4	0 10	0 15	odor established during	
5	0 38	0 23	cooking trials	
6	-0 06	0 04		
7	0 45	0 47		

Table 17a Mean preference of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Preference Score/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	-0 38	-0 47	-0 61	-0 70
2	-0 72	0 54	-0 57	-0 32
3	0 55	0 31	-0 30	-0 16
4	0 44	0 17	0 30	0 32
5	0 00	0 00	0 26	0 25
6	-0 40	-0 26	0 53	0 38
7	0 66	0 79	0 03	0 19

Table 18 Mean aroma scores of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	1 2	1 2		
2	1 6	1 7	no sensory evaluation	
3	2 0	2 6	due to strong fermented	
4	2 0	2 0	odor established during	
5	1 8	2 6	cooking trials	
6	1 9	2 8		
7	2 0	2 9		

Table 18a Mean aroma scores of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	1 7	1 5	1 0	1 6
2	1 8	1 7	1 0	1 4
3	2 7	2 8	1 0	1 3
4	2 6	2 5	1 2	1 7
5	2 2	2 6	1 4	1 5
6	1 8	2 3	1 1	2 0
7	3 3	2 2	1 2	1 4

Numerical Score	Equiv Aroma Description
1	With off odor
2	No aroma
3	Weak aroma
4	Moderately aromatic
5	Aromatic

Table 19 Mean color scores of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value//Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	3 2	3 3		
2	3 8	3 9	no sensory evaluation	
3	4 2	4 4	due to strong fermented	
4	4 1	4 2	odor established during	
5	4 4	4 4	cooking trials	
6	4 3	4 1		
7	4 1	4 5		

Table 19a Mean color scores of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	3 5	3 4	2 9	2 8
2	3 4	3 4	3 0	3 1
3	4 2	4 4	3 2	3 1
4	4 1	3 6	4 0	3 6
5	3 8	3 9	3 9	3 6
6	3 6	3 7	3 8	3 6
7	4 4	4 4	3 3	3 1

Numeral Value	Color Description
1	Blackish white
2	Grayish white
3	Yellowish
4	Creamish white
5	White

Table 20 Mean gloss scores of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Area			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	1 8	1 7		
2	2 6	3 0	no sensory evaluation	
3	2 6	3 4	due to strong fermented	
4	2 4	3 1	odor established during	
5	2 8	3 1	cooking trials	
6	2 6	3 1		
7	2 5	3 2		

Table 20a Mean gloss scores of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	2 2	2 2	1 4	1 4
2	1 8	2 1	1 6	1 8
3	2 6	3 3	1 4	1 9
4	2 7	2 6	1 9	2 2
5	2 1	3 0	2 0	1 9
6	2 0	1 9	1 9	2 2
7	2 0	3 4	1 7	2 0

Numeral Value	Gloss Description
1	Very dull
2	Dull
3	Moderately glossy
4	Glossy
5	Very glossy

Table 21 Mean flavor scores of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	2 3	2 3		
2	2 9	2 3	no sensory evaluation	
3	3 2	3 6	due to strong fermented	
4	3 0	3 2	odor established during	
5	2 7	3 3	cooking trials	
6	3 1	3 5		
7	3 0	3 8		

Numerical Score	Equiv Flavor Description
1	With off taste
2	Bland
3	Weak taste
4	Moderately tasty
5	Tasty

Table 21 Mean tenderness scores of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layer	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	2 3	2 4		
2	2 9	3 3	no sensory evaluation	
3	2 9	2 6	due to strong fermented	
4	2 7	2 9	odor established during	
5	3 0	3 2	cooking trials	
6	2 8	2 9		
7	2 7	2 8		

Table 22 Mean cohesiveness scores of milled cooked IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED COOKED				
1	2 9	2 5		
2	3 2	2 6	no sensory evaluation	
3	3 3	3 3	due to strong fermented	
4	3 0	3 2	odor established during	
5	3 2	3 3	cooking trials	
6	3 5	3 4		
7	3 2	3 3		

Numeral Value	Tenderness Description	Cohesiveness Description
1	Tough	Well separated
2	Chewy	Separated
3	Moderately Tender	Moderately sticky
4	Tender	Sticky

Table 23 Mean wholeness of grains scores of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	3 5	3 8	3 6	3 5
2	2 9	3 3	4 0	3 9
3	4 1	4 0	4 3	4 1
4	4 3	4 0	4 4	4 1
5	3 5	3 5	4 4	4 3
6	2 5	2 6	4 5	4 3
7	3 4	4 7	4 2	4 0

Numerical Score	Equiv Wholeness of Grains Description
1	Grits
2	Broken
3	Predominantly broken
4	Predominantly whole grain
5	Whole grains

Table 24 Mean brittleness of grains scores of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	4 1	4 3	4 5	4 2
2	4 1	4 0	4 7	4 2
3	4 3	4 5	4 7	4 3
4	4 7	4 2	4 8	4 4
5	4 2	4 1	4 6	4 5
6	4 1	3 9	4 8	4 5
7	4 7	4 5	4 6	4 3

Numerical Score	Equiv Brittleness of Grains Description
3	Soft
4	Soft but yielding ("makunat")
5	Brittle

Table 25 Mean grain translucency scores of milled raw IR64 samples from various layers of stored wet paddy in a Volcani cube set-up for different storage durations, 1998

Pile Layers	Mean Value/Storage Period/Site			
	Three (3) Months		Six (6) Months	
	UPLB	BAY	UPLB	BAY
MILLED RAW				
1	2 8	2 8	2 0	1 8
2	2 4	2 6	2 6	2 5
3	3 3	3 5	2 9	2 6
4	3 4	3 0	3 0	3 2
5	3 0	3 1	3 2	3 0
6	2 7	2 5	3 1	2 8
7	3 4	3 4	3 0	2 6

Numerical Score	Equiv Grain Translucency Description
2	Opaque
3	Chalky
4	Moderately chalky
5	Translucent

Appendix 4 to Final Report C12-057

(accepted for presentation at 19th ASEAN and 1st APEC Seminar on Postharvest Technology to be held in Ho Chi min City, Vietnam 9-12 November 1999)

PREVENTION OF MOISTURE MIGRATION IN SEALED GRAIN STACKS STORED IN THE OPEN IN THE TROPICS USING REFLECTIVE COVERS

Jonathan Donahaye[1], Shlomo Navarro[1], Filipinas Caliboso[2], Glory Sabio[2], Gemma Mallo[2] and Joel Dator[2]

1Agricultural Research Organization Department of Stored Products Bet Dagan Israel
2Bureau of Postharvest Research and Extension Munoz, Philippines

Abstract

A sealed structure that provides protection of grain without the use of chemical pesticides and termed "Volcani cube" was used in these experiments A major advantage of the Volcani cube is that it can be used to safely store grain outdoors when no suitable storage buildings are available However, under tropical conditions, when grain is stored in the open with no shade, ambient diurnal temperature fluctuations, can create temperature gradients within the stack that cause convection currents to carry moisture to the upper layers of grain To overcome this, an upper insulating layer of bags containing straw or husks was employed Under Filipino conditions this solution enables safe storage of maize and paddy for periods of up to three months, while for more extended periods the top moistened layer of husks should be replaced with dry material This method, although solving the problem, suffered from the inherent disadvantages of reduction in effective storage capacity, the necessity to procure and transport material to fill the bags, and the added expense of bags not used for storing grain

In a search to develop an alternative inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, the use of a shade screen placed above the cube was investigated This material described as a knitted thermal screen is formed from aluminum coated high density polyethylene threads

Trials in Israel and the Philippines showed that the reflective covers had a strong attenuating influence on temperature gradients and condensation at the top of the cubes on condition that a space for free movement of air was allowed between the cover and the plastic liner For dry paddy, it was shown that after five months storage under a reflective cover, no perceptible increase in moisture content was found at the top of the stack and the grain remained in good condition (306 words)

INTRODUCTION

Two R&D projects carried out over the past nine years by The Bureau of Postharvest Research and Extension (BPRE) in the Philippines, with the cooperation and support of the Agricultural Research Organization (ARO) in Israel, have focussed on the outdoor storage of grain inside hermetically sealed plastic liners termed Volcani cubes (Alvindia et al, 1994, Caliboso et al, 1997, Donahaye, et al, 1998, Navarro, et al, 1995, Navarro, et al, 1997, Navarro and Donahaye, 1998) The practical outcome of the first project was to strengthen the present policy of the Filipino Government which is directed at providing farmer cooperatives with on-site storage units so as to decentralize storage of the national grain reserve as well as provide rural communities with a higher level of food security Implementation of this policy is under way, and already the concept of sealed storage to protect dry grain from insect infestation has been widely promoted together with the distribution of the flexible plastic outdoor storage cubes that were developed during the course of this project In 1998, about 200 units were distributed to farmers' cooperative recipients nationwide Presently, government orders have been placed to purchase additional units for distribution among farmer cooperatives The second project was designed to provide a solution to the acute regional problem where paddy-rice is harvested at high moisture contents (MCs) during the monsoon season This paddy must then be dried rapidly to a safe MC in order to prevent it from molding and rotting However, if the paddy is dried rapidly from about 30% to the required "safe" MC, the grains suffer stress resulting in cracking and breakage To overcome this problem a two-stage drying procedure is advocated where the paddy is initially dried to 18% (intermediate MC), at which stage yeast and bacterial activity are suppressed, followed by a second stage drying from 18 to 14% MC to prevent the development of storage molds The technology being developed in the second project is intended to enable farmers to overcome the bottleneck that occurs at the second drying stage by providing them with a means of storing the intermediate MC paddy under tightly sealed conditions and thereby prevent spoilage for prolonged periods until drying by sun or machine is again an available option

One significant finding in the first project was that under Filipino conditions, for dry paddy or corn stored in cubes outdoors with no shade, the diurnal temperature fluctuations of the ambient, created temperature gradients within the cubes that caused convection currents to carry moisture to the top of the stack To overcome this, an upper insulating layer of bags containing rice hulls or corn cobs was advocated This method effectively solved the problem but also suffered from several inherent disadvantages, namely reduction in effective storage capacity of the cube, necessity to procure and transport the husks or corn cobs and fill the bags, and the added expense of bags not used for storing grain It was shown that under Filipino conditions this method enables safe storage for periods of up to three months For more extended time periods the wet top layer of husks or corn cobs should be replaced (Navarro et al 1995)

In the second project it was envisaged from the outset that when intermediate MC grain (circa 18% MC), is stored outdoors this phenomenon would also occur and would probably be even more critical since any rise above 18% MC is liable to trigger the anaerobic metabolism of bacteria and yeasts that have a strong influence on grain quality, particularly taste and aroma

In a search to find an alternative inexpensive and convenient method of insulating the stack from diurnal temperature fluctuations, the use of a shade-providing awning consisting of "Polysac - Aluminet" was investigated This material is described by the manufacturer as a knitted shade cloth for use as a thermal screen and formed from aluminum coated high density polyethylene threads The trials described here were undertaken to study the effectiveness and applicability of these screens in protecting the grain stacks The first trials were carried out in Israel using a 10 ton capacity cube containing wheat, in order to obtain preliminary data and to fine-tune the method Later trials were carried out both in Israel and the Philippines

TRIALS IN ISRAEL

Materials and Methods

The first trial in Israel was directed at simultaneously comparing the day-time temperature gradients at the top of a storage cube, between unprotected and protected segments of the upper liner Two densities of shade material were compared during day-time only, and the insulating effect of the two types was examined both when the cover was spread directly over the top of the liner (Fig 1a) and also when it was separated from the liner by a distance of 10 cm using spacers (Fig 1b)

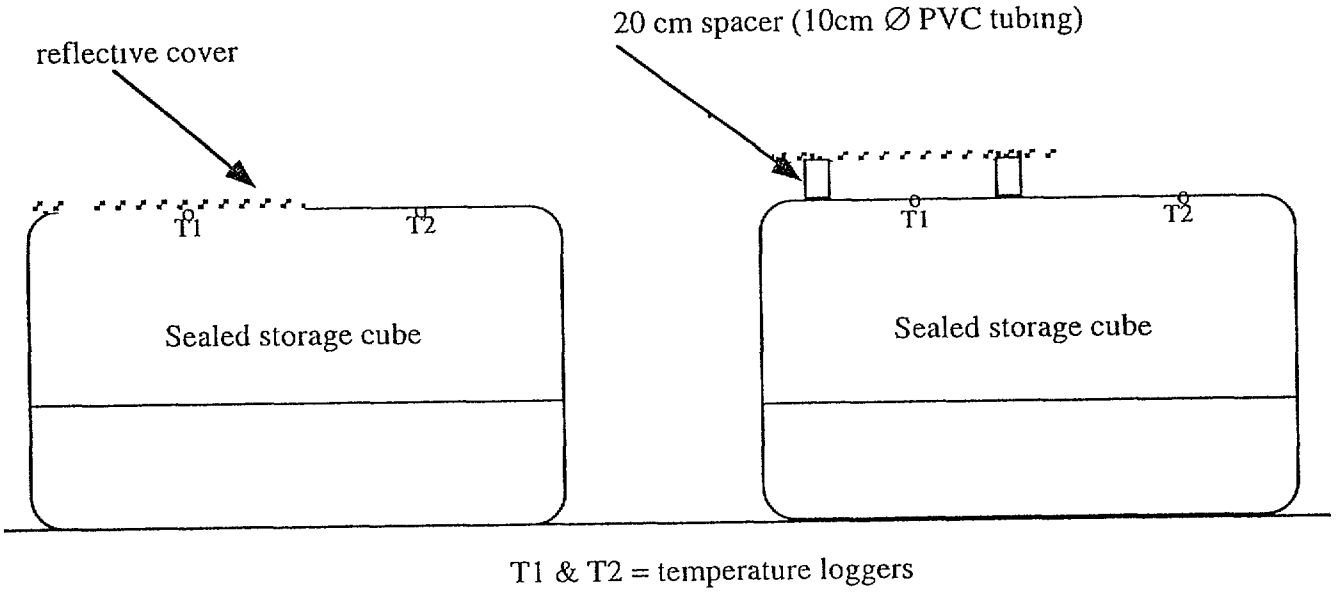
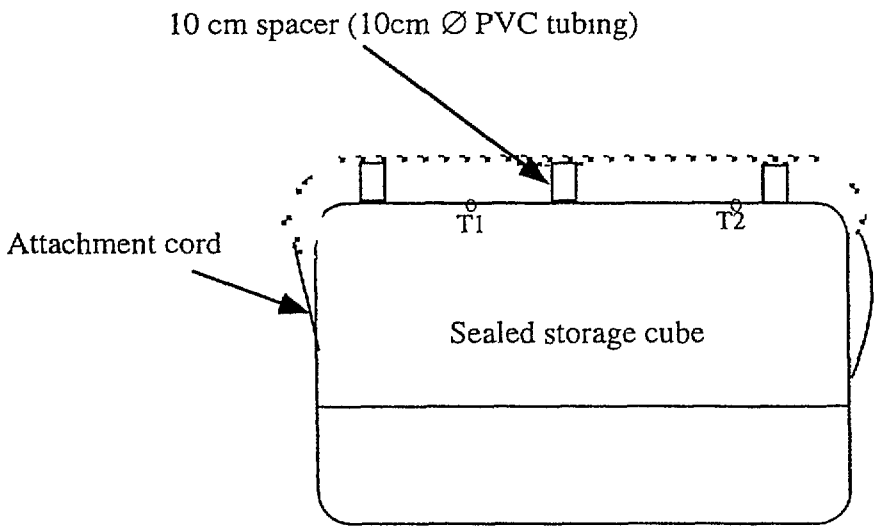


Fig 1 Set-up in first Israeli trial to compare day-time temperatures at the upper liner, between covered and uncovered section, and between cover with spacers and cover without spacers

Results of this first trial were inconclusive even though they indicated a decrease in temperature gradient of the stack when protected by the cover Therefore a second trial was undertaken in which temperature measurements were recorded using data-loggers ("Hobo", Onset Computer Corp) to enable temperature gradients to be monitored at night-time, when condensation problems are more acute However, in this case, an entire cover was used, and a 7-days on and 7-days off regime was employed Here, the problem of fixing the cover above the cube became evident To "solve" this problem, the edges of the cover (separated from the cube by spacers) were attached to cords that were drawn down and tied to the tension straps around the cube (Fig 2)

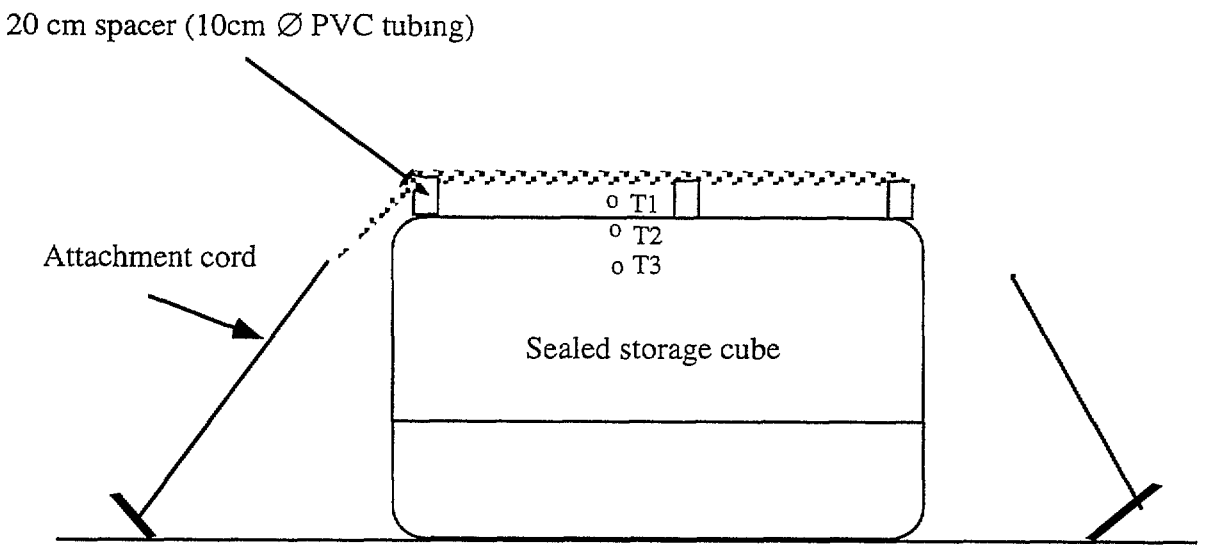
However, in this way the sides of the space above the cube were sealed by the cover We believe that although we recorded a small reduction in temperature gradient due to the cover, the absence of this gap between the top surface of the cube and around the borders of the stretched cover-screen may have resulted in trapping the heat between the cover and liner during day-time Later, this heat dissipated rapidly upwards through the screen as the air above it cooled towards dusk Again, results of this trial are not given here



T1 & T2 = thermocouple points

Fig 2 Trial using protective cover pulled down at sides and attached to tension straps

The third trial in Israel was designed to overcome this problem (Fig 3)



T1, T2 & T3 = Data loggers

Fig 3 Trial in which air could freely move between the cover and the upper liner of the cube

In this trial the reflective cover was stretched over the top of the cube using 20cm spacers, and care was taken to ensure that the cover was not brought down at the sides, but remained with a gap to permit free air movement beneath the cover At weekly intervals the cover was removed or replaced so that three alternating series of recordings (cover on, cover off) were obtained Three data loggers, set to record temperatures at one hour intervals, were placed at the center of the cube, one above the liner, one below the liner, and one within the upper layer of bags at a depth of 10 cm At the end of the trial the recordings were down-loaded into an Excel spreadsheet

Results

A summary of the amassed data is provided in Table 1 The Table clearly reveals the attenuation in daily temperature fluctuations caused by the reflective cover Over the course of the trial, the average daily temperature above the liner was about 7 degrees lower, with the cover in place, than without it and this was particularly evident during the day-time (hours of sunlight) when there was a 10 to 15 degree temperature difference

Table 1 Average weekly temperatures and temperature gradients recorded with and without a reflective cover placed above a 10 ton capacity Volcani cube at Bet Dagan Israel (28th March to 10th June 1998)

a) Weekly averages of 24 hour recordings

Week (1998)	reflective cover	above liner	below liner	10cm	Ambient temp	Temp gradient	Temp gradient	Temp gradient
		(A)	(B)	(C)		(A-B)	(A-C)	(B-C)
Average	With	22 7	22 3	21 7	21 6	0 4	1 1	0 6
Average	Without	26 9	26 1	23 9	22 6	2 4	4 6	2 2

b) Weekly day-time averages of sunlight hours (9am to 6pm)

Week (1998)	reflective cover	above liner	below liner	10cm	Ambient Temp	Temp gradient	Temp gradient	Temp gradient
		(A)	(B)	(C)		(A-B)	(A-C)	(B-C)
Average	With	29 2	27 1	21 1	26 3	2 1	8 1	6 0
Average	Without	43 5	35 8	23 3	26 7	7 8	20 3	12 5

c) Weekly night-time averages (7pm to 8am)

Week (1998)	reflective cover	above liner	below liner	10cm	Ambient Temp	Temp gradient	Temp gradient	Temp gradient
		(A)	(B)	(C)		(A-B)	(A-C)	(B-C)
Average	With	18 1	18 9	22 0	18 3	-0 8	3 9	-3 2
Average	Without	18 3	19 5	24 3	19 6	-1 2	6 0	-4 8

The temperature gradients shown in the Table reveal the conditions that generate a continuous rhythm of convection currents, when, during the night, moisture is transported to the surface layers, and during the day-time the surface layers lose moisture as they heat up In the Israeli climate, we have shown (Navarro et al , 1996) that throughout the year there is no marked net-moisture transfer to the surface in the storage cubes, and no special precautions need be taken However, already it has been already shown that for outdoor storage of dry grain in the Philippines, there was a continuous though gradual process of moisture transfer to the surface due to the fact that the net moistening effect at night was greater than the net drying effect during the day Therefore it was evident that trials would have to be carried out in the Philippines to verify whether this reflective liner could serve as a replacement for the insulating top layer of agricultural wastes as used in the present storage method for dry grain, or if it can effectively retard moisture migration during the storage of intermediate MC paddy under tropical conditions

TRIAL IN THE PHILIPPINES

Materials and Methods

This trial was carried out in conjunction with a field trial for storage of intermediate MC (approximately 18%MC) paddy in order to evaluate quality conservation, using two ten ton capacity cubes, one for a three month, and one for a six month duration

An additional cube containing dry paddy at 14% MC was set up for 5 months under a separate reflective cover but was not monitored for temperature gradients

The cubes were set up at the BPRE (NAPHIRE) compound in Muñoz using freshly harvested paddy (IR64) that was dried to approximately 18% MC from higher MCs using a fluidized bed dryer, and using paddy sun-dried to 14%MC

In this trial the 70% density reflective covers were suspended over the cubes using a series of poles and guy ropes to create a tent shaped awning that also partially protected the sides Temperatures were logged hourly above the liners, below the liners, 10 cm within the upper grain layer, and in the central core of the stacks at 18%MC The set-ups were as shown in Fig 4

Moisture contents at the different stack layers within the cubes were recorded at the beginning and end of both storage periods

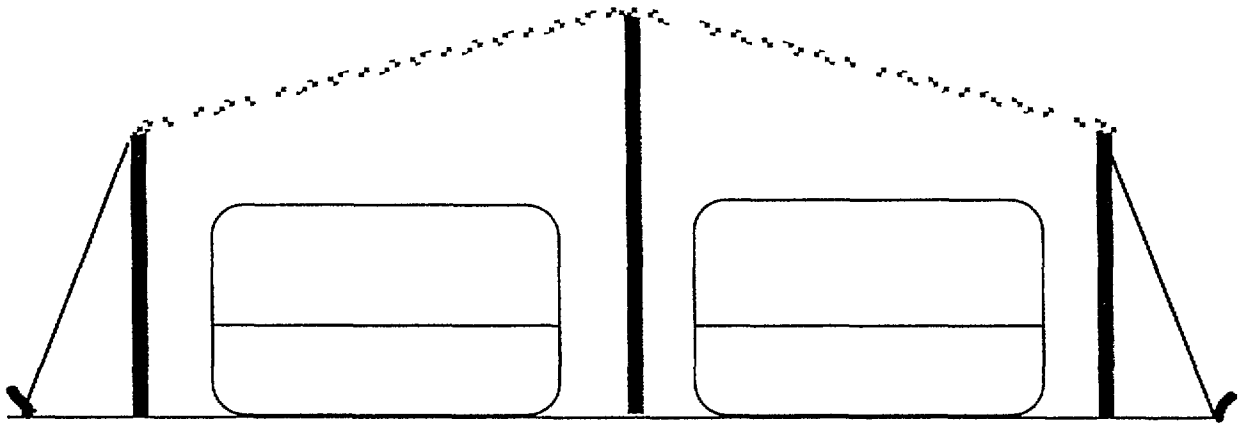


Fig 4 Experimental set-up of reflective liner at Muñoz, Philippines

Results

A summary of temperature gradients recorded over a representative period of the different storage durations (November - December) is given in Table 2 For comparison, day-time temperature gradients recorded during a previous trial without reflective cover (July - August) are also provided

The Table shows that with the reflective cover set up as an awning over the cubes, temperature gradients both at night and day-times were small and compared favorably with those recorded in Israel

Table 2 Summary of 16 days of recordings taken by temperature loggers in a Volcani cube protected by a reflective cover at Muñoz Philippines

a) Average daily

Reflective cover (23 November 7 December)						
Temp (°C)	**Above**	**Beneath**	**10 cm**	**Temp gradient**	**Temp gradient**	**Temp gradient**
	Liner	**Liner**	**Deep**			
	A	**B**	**C**	**A-B**	**A-C**	**B-C**
Average daily	28 4	27 6	28 0	0 8	0 4	-0 4
Average max	36 6	35 2	30 4	3 0	8 1	6 9
Average min	23 6	22 8	26 2	1 2	-3 4	3 8

b) Average day-time

Reflective cover (23 November 7 December)						
Temp (°C)	**Above**	**Beneath**	**10 cm**	**Temp gradient**	**Temp gradient**	**Temp gradient**
	Liner	**Liner**	**Deep**			
	A	**B**	**C**	**A-B**	**A-C**	**B C**
Average daily	33 3	31 8	28 6	1 6	4 8	3 5
Average max	37 0	35 1	30 3	3 1	8 3	6 9
Average min	29 1	27 0	26 1	-0 9	1 2	1 4
No cover (9 July 26 August)						
	A	B	C	A-B	A-C	B-C
Average daily	39 88	33 15	30 98	6 73	8 89	2 17
Average max	50 88	39 43	33 41	14 23	19 84	6 41
Average min	30 12	29 69	28 36	0 73	-1 12	2 43

c) Average night-time

Reflective cover (23 November - 7 December)						
Temp (°C)	**Above**	**Beneath**	**10 cm**	**Temp gradient**	**Temp gradient**	**Temp gradient**
	Liner	**Liner**	**Deep**			
	A	**B**	**C**	**A-B**	**A-C**	**B-C**
Average nightly	25 3	24 9	27 6	0 4	-2 8	-2 4
Average max	28 9	28 9	29 9	1 2	-1 0	-0 9
Average min	23 6	22 8	26 0	0 4	-3 8	-3 4

Calculations based on average night temperatures read-outs show that since 18% MC paddy has an equivalent EMH of 92% RH the water content of the air at 10 cm depth, would be about 25 1g/m^3 at 27 6°C If this air rises due to the night-time temperature gradient and cools at the surface below the liner to 24 9°C then at 100% RH it would contain 23 1g/m^3 Namely there would be a condensation of 1 8 gm for every cubic meter of air reaching the upper surface

Although the data-logger records show that for most of the night duration, air at 92% RH (=18% grain EMC) would become saturated when in contact with the upper plastic liner, the very small temperature gradient would produce only feeble convection currents For a direct evaluation of the net effect of moistening of the surface layer at night-time and drying during the day-time, the MCs at the top of the stack were examined after 3 and 6 months These findings are given in Tables 3 and 4

Three months storage 18%MC From Table 3 it can be seen that after 3 months, moisture migration had caused an increase of 4% MC in the top layer and 2% MC in the second layer Since MCs above 18% (EMH = 92%) enable the development of yeasts and bacteria that can cause rotting and the development of unpleasant odors, the organoleptic characteristics of the paddy were also seriously affected

Table 3 Average moisture contents of intermediate moisture content paddy hermetically stored in a Volcani cube in the Philippines for 3 months

Position	Composite sample (Av 6 readings	Beginning 22-Nov-98	3 months 23-Feb 99	Composite sample (all bags in each layer of stack 23 Feb 99	Average (3 readings)
Top	1	18 0	19 3	Top 1	22 0
	2	17 9	19 8	2	20 4
	3	18 0	20 1	3	18 0
				4	18 0
Middle	1	18 0	17 2	5	18 3
	2	18 0	17 3	6	18 3
	3	18 2	17 5	Bottom 7	18 0

Table 4 Average moisture contents of intermediate moisture content paddy hermetically stored in a Volcani cube for 6 months

Position	Composite sample (Av 6 readings	Beginning 22-Nov-98	3 months 21-May-99	Composite sample (all bags in each layer of stack) 21-May-99	Average (3 readings)
Top	1	18 3	24 8	Top 1	28 5
	2	17 5	28 6	2	21 0
	3	17 6	21 4	3	18 2
				4	17 7
Middle	1	18 0	18 3	5	17 0
	2	17 9	18 6	6	17 0
	3	17 6	18 4	Bottom 7	16 7

Six months storage 18%MC Table 4 shows that the continued upwards movement of moisture resulted in even higher MCs at the upper layers at the end of the 6 month storage period However, here again the accumulation of moisture was only noted in the top two layers

Dry grain storage At the end of the 5 month storage period, (7th December 1998 to 5th May 1999) the stack was opened and examined, and although a comprehensive examination of moisture contents by stack layer was not undertaken, the spot tests at the top of the cube revealed that there was no perceptible increase in MC, and the grain was dry throughout the stack

SUMMARY AND CONCLUSIONS

The trials in Israel showed that the reflective covers had a strong attenuating influence on the development of temperature gradients and condensation at the top of the Volcani cubes placed in the open, providing a space for free movement of air was provided between the cover and the plastic liner This was confirmed in the Philippines, but field trials with 18% MC paddy showed that this insulating effect was not sufficient to prevent a gradual build-up of moisture at the surface layer However, for dry paddy, it was shown that after five months storage under a reflective cover, no perceptible increase in moisture content was found at the top of the stack and the grain remained in good condition

As a result of these findings, a decision was taken to discontinue recommendations for inclusion of a protective layer of agricultural wastes at the top of the stack to be replaced every three months (Navarro et al 1996) Instead, a suitably sized reflective cover would be included in the carrying bag of the storage-kit, and instructions on setting up the cover would be added to the manual Two additional configurations for positioning the reflective cover are given in Fig 5

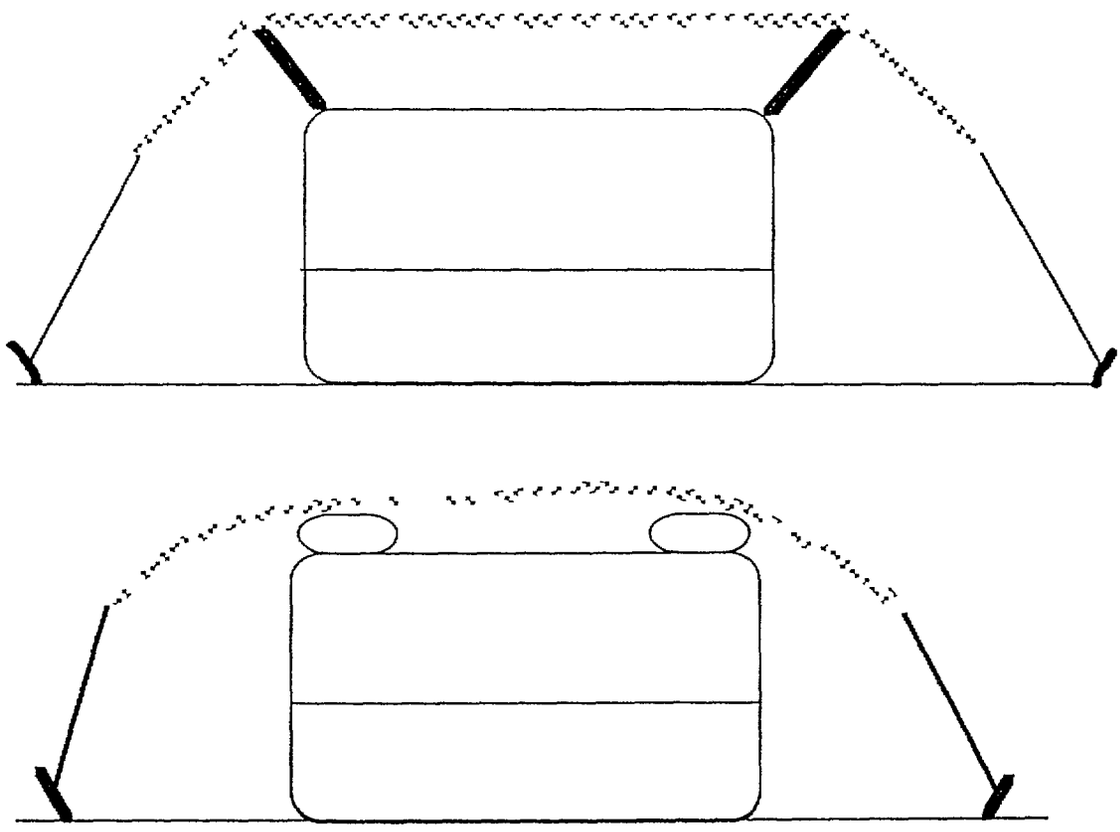


Fig 5 Additional configurations for positioning the reflective cover above the storage cube

Acknowledgement This research was supported under Grant No TA-MOU-94-C12-057 funded by the U S -Israel Cooperative Development Research Program of the U S Agency for International Development

Literature cited

Alvindia, D G , Caliboso, F M , Sabio, G C and Regpala, A R (1994) Modified atmosphere storage of bagged maize outdoors using flexible liners a preliminary report In Highley E , Wright E J , Banks H J and Champ B R Eds *Proc 6th Int Wkg Conf Stored-product Protection* 17-23 April 1994, Canberra Australia CAB International Oxon **1,** 22-26

Caliboso, F M , Navarro, S , Alvindia, D G , Donahaye, E J , Sabio, G C and dela Cruz, M T (1997) Effect of gastight storage on growth of fungi in paddy stored outdoors In *Proc Int Conf Controlled Atmosphere and Fumigation in Grain Storages,* 21-26 April 1996, Nicosia, Cyprus pp 135-144

Donahaye, E J , Andales, S C , Chernoguz, D , Navarro, S , Azrieli, A and Miriam Rindner (1998) Respiration rates of paddy at different temperatures and moisture contents In Proc 18th ASEAN Seminar on Grains Postharvest Technology, 11-13 March 1997, Manila, Philippines pp 145-152

Donahaye, E J , Andales, S C , Navarro, S and Caliboso, F (1999) Self regulated atmospheres to prevent fungal damage in moist paddy Final report of Project Number TA-MOU-94-C12-057 submitted to USAID 32 pp

Navarro, S , Donahaye, E , Caliboso, F M , and Sabio, G C (1996) Application of modified atmospheres under plastic covers for prevention of losses in stored grain Final Report submitted to U S Agency for International Development, CDR Project No C7-053, August 1990 - November 1995 32 pp

Navarro S Caliboso, F M , Sabio, G C and Donahaye, E J (1997) Quality conservation of paddy stored under gas-tight seal outdoors in the Philippines In *Proc Int Conf Controlled Atmosphere and Fumigation in Grain Storages,* 21-26 April 1996, Nicosia, Cyprus pp 159-168

Navarro S , Donahaye, E J , (1998) Outdoor Storage of Corn and Paddy Using Sealed-Stacks in the Philippines In Proc 18th ASEAN Seminar on Grains Postharvest Technology, 11-13 March 1997 Manila, Philippines pp 225-236

85