The Agribusiness Project (TAP)

Under Sub Agreement UAP-ISC-012-001-CNFA

Cold Chain Interventions
Final Report
for the Agribusiness Project

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DISCLAIMER

1 Contents

2 Lists of Acronyms and Definitions

AOR	Agreement Officer's Representative (USAID)
ADDP	Agribusiness Development and Diversification project
ASF	Agribusiness Support Fund
AusAid	Australian Agency for International Development
CNFA	Non-governmental organization formerly known as Citizens' Network for Foreign Affairs
FSC	Farmer Service Center
GDP	Gross domestic product
KFS	Kissan Field Schools
KPK	Khyber Pakhtunkhwa
kW	Kilowatt
LDDB	Pakistan Livestock and Dairy Development Board
LFBA	Livestock Farmers & Breeder Association
MFI	Microfinance Institution
NWFP	North West Front Provinces
PBS	Pakistan Bureau of Statistics
PFVA	Pakistani Fruit and Vegetable Association
PLDDB	Punjab Livestock and Dairy Development Board
Rs	Pakistan Rupee
SME	Small to medium business enterprise
SMEDA	Small and Medium Development Company
TAP	The Agribusiness Project
USAID	United States Agency for International Development
USDA	Unites States Department of Agriculture
VC	Value Chain

3 ACKNOWLEDGEMENTS

The help provided by Salman Khan and Shafqat Sayed is acknowledged who either both or one accompanied me on the travels and provided a lot of valuable input.

Mr. Shamsher Khan organized the initial itinerary and ensured that the visit to Pakistan and the arrangements went smoothly.

The Stakeholder meetings, other meetings and technical visits were all useful, and the way that everybody was so cooperative, including answering questions that they must have thought either irrelevant, obvious or naïve. Without their valuable input this assessment would not have been possible.

I am grateful to Dr. Babar Bajwa who provided a very useful sounding board for various ideas and concepts and the professional way in which he assisted with these sessions.

4 EXECUTIVE SUMMARY

Following the January visit where a number of possible interventions were identified, this report goes into more detail on those which were considered most important. The themes are to assist in provision to the Pakistani supermarket and export sector for fresh produce with particular emphasis on reducing postharvest losses and providing a uniform product.

Detailed description of a cold store and cooling unit which could be used either for kinnow or peaches or other produce is given. This unit could be used as a standard for new stores. The unit is designed to cool and store 60t of kinnow a day, which is sufficient for two refrigerated containers a day.

The specifications for both a seed potato store for hill areas and an evaporative cooling kit for small farmers are provided which, it is hoped, can now be taken up by contractors. Areas for consideration in refurbishment of cold stores for ease of operation and increased efficiency are also suggested.

The format and outline content for one and two week training courses are given, both based in Pakistan and abroad.

5 BACKGROUND AND OVERVIEW OF THE INDUSTRY

A background and overview of the industry was given in the previous report in January; however, the statistics for exports have recently been published that provide an insight into developments.

The big international trade fair Fruit Logistica was held in Berlin in February and was attended by a group funded by the project as well as the consultant and provided a good focus on the challenges and opportunities for Pakistani produce with particular emphasis on uniformity and continuity of supply.

The crisp factory of Frito Lay / PepsiCo is now taking 500t of potatoes each and every day and is looking to expand production. Crisps are being exported to Sri Lanka and Indonesia and provide a very good example of value added export. There are intentions to expand production for national and international markets, and it is thought that work with projects like this could be beneficial even in a training role.

Pakistani fruit exports increased by 1.82% over the past eight months. The exports of fruits during the period July-February (2012-13) were recorded at $276.159 million against $271.233 million during same period of last year. According to data from the Pakistan Bureau of Statistics (PBS), the fruit exports on a month on month basis also increased by 3.02% during February 2013 against the same period of last year; whereas, when compared to January 2013, fruit exports decreased by 21.3 percent. Fruit worth $54.7 million were exported during February 2013; whereas, volume was $53.1 million and $69.51 million during February, 2012 and January 2013 respectively.

Similarly, vegetable exports from the country during July-February (2013-12) surged by 51.08% against the same period of last year. Vegetable exports increased from $78.616 million in July-February (2011-12) to $118.77 million in July-February (2012-13). Vegetable exports, on a month on month basis increased by 46.58% in February, 2013 when compared with the same month of last year and decreased by 2.93% in February 2013 against January 2013. Vegetable exports increased from $20.125 million in February 2012 to $29.5 million in February 2013 whereas the exports in January 2013 remained $30.388 million.

The overall food exports of the country during first eight months of current fiscal year (2012-13) increased by 9.22%. (Source: pakobserver.net Publication date: 4/16/2013)

6 BRIEF SWOT ANALYSIS OF THE INDUSTRY

Strengths	**Weaknesses**
• Devalued rupee provides good export opportunities for both fresh produce and value added (such as potato crisps) • Availability of good arable land and rain fed irrigation • Good links through the Pakistanis abroad to international markets	• Lack of appropriate training facilities and hence lack of trained staff • Erratic and limited power supply • Poor infrastructure and existing facilities • Next farm rather than another country seen as the biggest competitor
Opportunities	**Threats**
• Low costs in the market place • Programmes such as ASF to give impetus to development	• Security situation • Reluctance to cooperate with each other

7 RECOMMENDATIONS/INTERVENTIONS

This report is developing the recommendations of the report produced after the January visit. The areas considered are:

- cold store and cooling unit
- seed potato store for hill areas
- training possibilities
- the refurbishment of existing cold stores and
- establishment of evaporative cooling packages.

These five are considered in the following sections.

7.1 Cold Store and Cooling Unit for kinnow or peach or similar

The proposal is to have a standard cold store which also has the capacity for cooling product as well. The proposed system is effectively the same for 60t of kinnow or 50t of peaches or similar, and it is assumed that the unit would be installed within an existing packhouse.

Size of 60 tonnes is the capacity for kinnow (or 50t for peaches, which have a lower packing density) to hold sufficient product for two 40 foot refrigerated marine containers. It is assumed that the ambient temperature is 18^{o}C for kinnow and 25^{o}C for peaches or similar.

It is assumed that the whole quantity in the store has to be at dispatch temperature within 24 hours. The dispatch temperature is taken as 5^{o}C for kinnow and 3^{o}C for peaches.

The store would be panel construction to permit easy cleaning which is particularly important if there is a large turnover of product as would be expected for kinnow, etc.

The calculations for the store are given in Appendix A.

The standard kinnow carton as shown below that is used in Pakistan has a smaller than 5% vent area and this will result in lower cooling efficiencies and, hence, slower cooling and higher energy usage.

Photo 1 Examples of Fruit Cartons with Small Vents

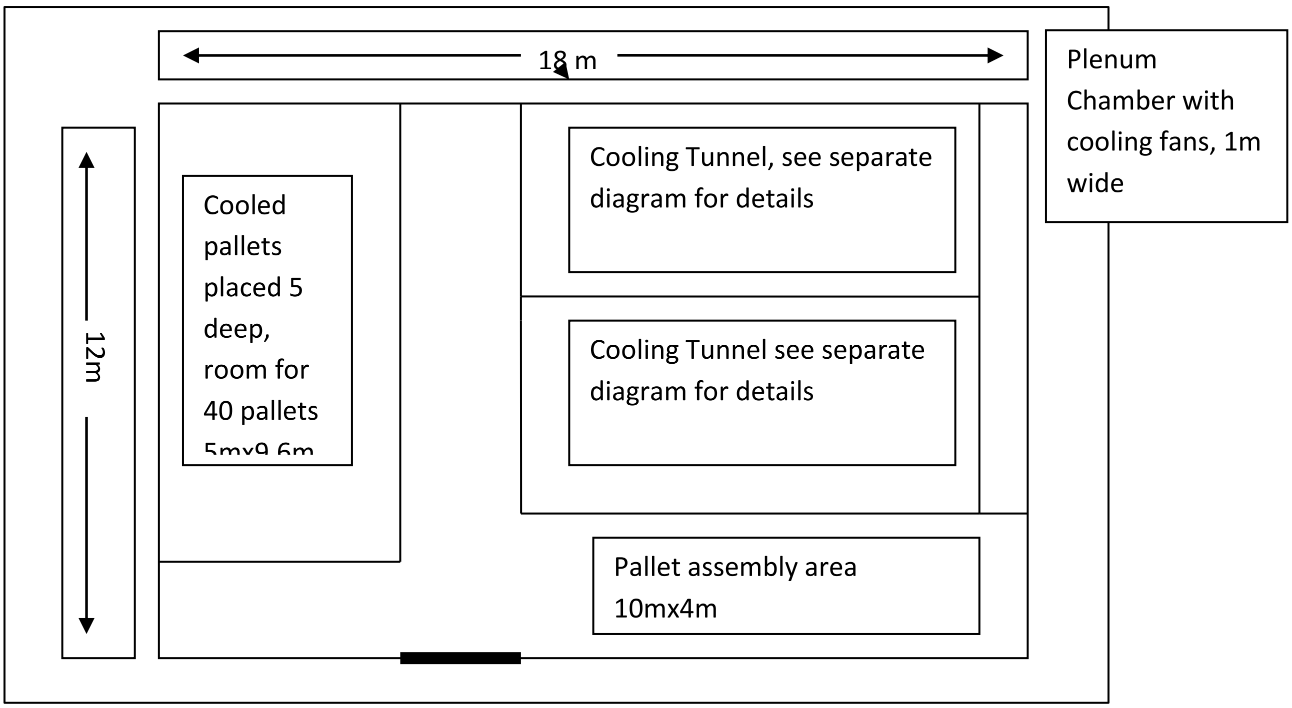
	
Carton showing small vents	Another example of cartons with small vents

Refrigeration capacity for a forced air cooler is calculated the same way as it is for cold storage. Heat inputs are summed from the following sources:

- product heat loss
- fans and motors
- heat loss from packing materials
- air infiltration
- heat conducted through cold room exterior surfaces
- heat input from lights, lift trucks and people and
- product respiration

Heat released from the product is great at the beginning of the cooling and drops rapidly during the process. The refrigeration system must be sized to handle the high initial heat release. A refrigeration capacity of approximately 70 kW of cooling should be adequate. The actual cooling required is close to 35 kW but the actual efficiency of cooling is normally about 50%, which is why 70 kW is suggested for kinnow. The same store design can be used for peaches; but with 50t rather than 60t and a cooling efficiency of 70% with the more vented carton, the total refrigeration capacity is effectively the same.

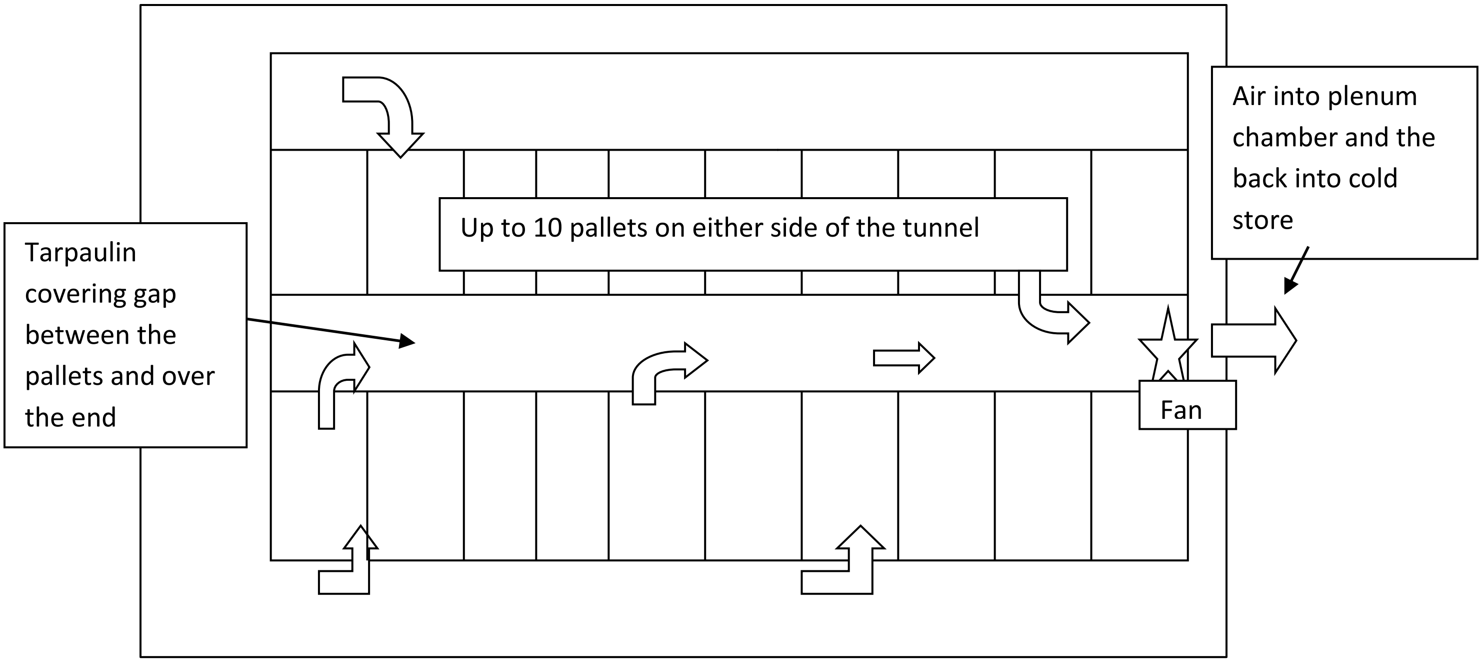
Figure 1 Sketch of Layout for the Cold Store and Cooling Unit

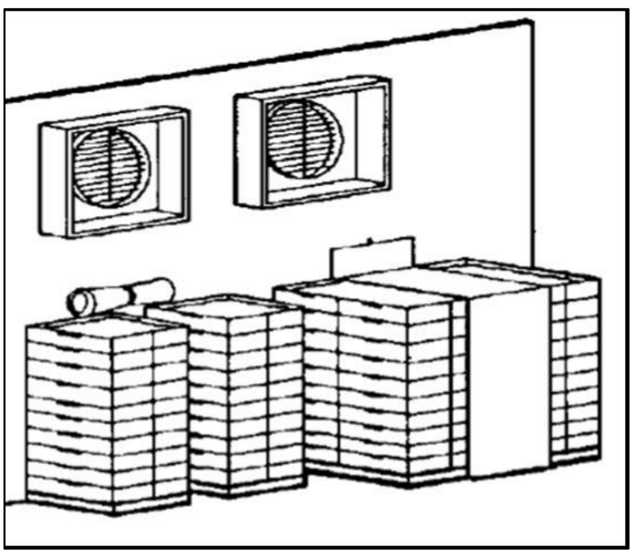


Space for 60 pallets (1.2 x 1.0m) each with 750kg stacked in cartons. A pump truck will be required for moving the pallets around.

The cartons of fruit can be either assembled onto pallets outside the store and brought in and placed in the cooling tunnel or assembled within the cold store. The decision will be mainly made by the rate at which the product is coming in. If it comes in gradually, then the assembly can be performed within the cold store, but if it comes large quantities all at once, then the assembly would have to be outside the store but still definitely in the shade.

Following pallet assembly, the pallets would be placed so as to form the cooling tunnel. Therefore all carton vents need to be line with the intended airflow. The tunnel can start cooling with only two pallets. Once the pallets have been cooled they can be moved to the other side of the cold store.



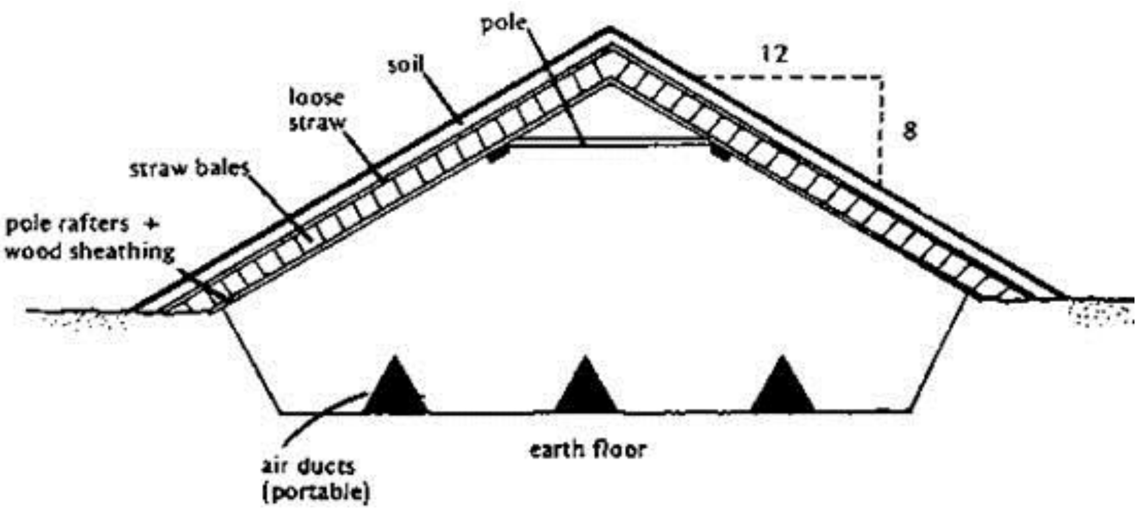


Direction of airflow

7.2 Seed Potato Storage for Hill Areas

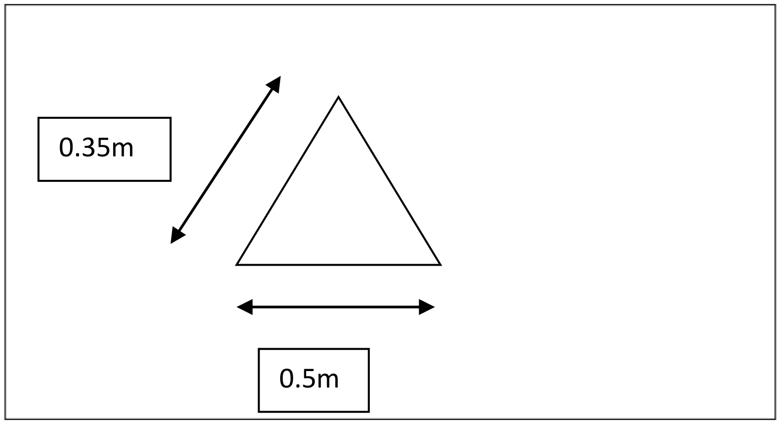
The function of seed potato storage is to keep the potatoes in a dormant state until they are required to sprout and this is best achieved by keeping the potatoes cool but not frozen. Potatoes do respire and produce some heat and moisture all of the time. The objective of the design shown below is to provide a system that maintains the potatoes but does not require inputs such as electricity. Work that produced successful results has been done in some hill areas where the store is loaded and then left above the snow line for months. The design below is similar, but for areas where the snow may not be present for such a long duration, it may be beneficial to have some cool, but not frozen, air passing through the tubers.

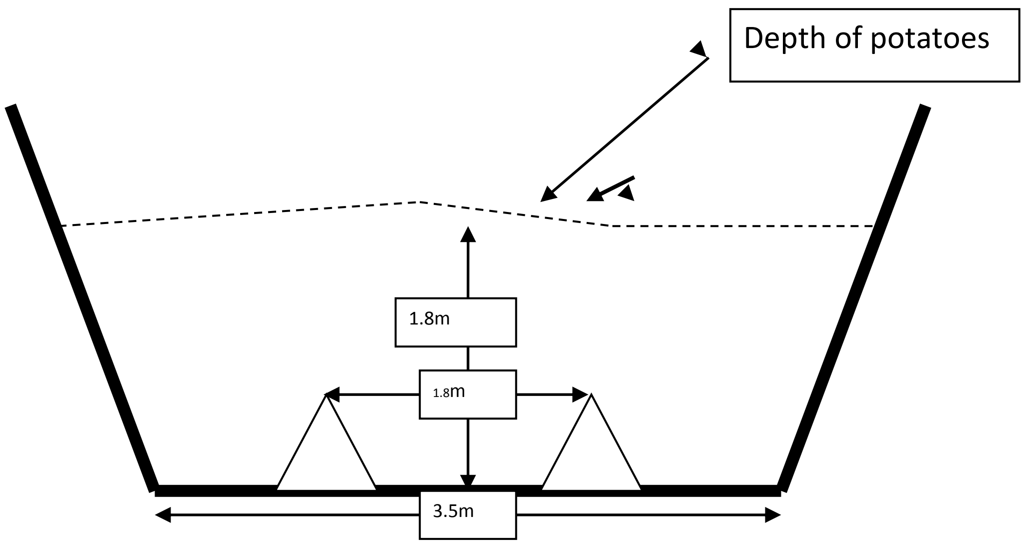
- For 3-4 month storage of potatoes, a self-supporting storehouse can be constructed. A pit is dug about 3m (10 ft.) deep and wooden air ducts are placed along the well-drained earthen floor. The roof of the building is constructed of wood, and then covered with straw and a thick layer of soil. The ends of the ducts are open but can be shut with a straw bale in frosty weather. A vertical chimney (not shown) may be used to encourage some ventilation. The store would use the cool ambient air at harvest and after the snow season to extend the storage life of the potatoes.



- Possible dimensions for 25t
- Width 3.5m, depth of potatoes 1.8m, length 6m
- Two “A” ducts to be placed in the base with a distance of 1.8m between them. The dimensions of the ducts to be such as to give 0.5m base and side of 0.35m, probably made of wood with slatted sides or could be made with strong wire mesh.

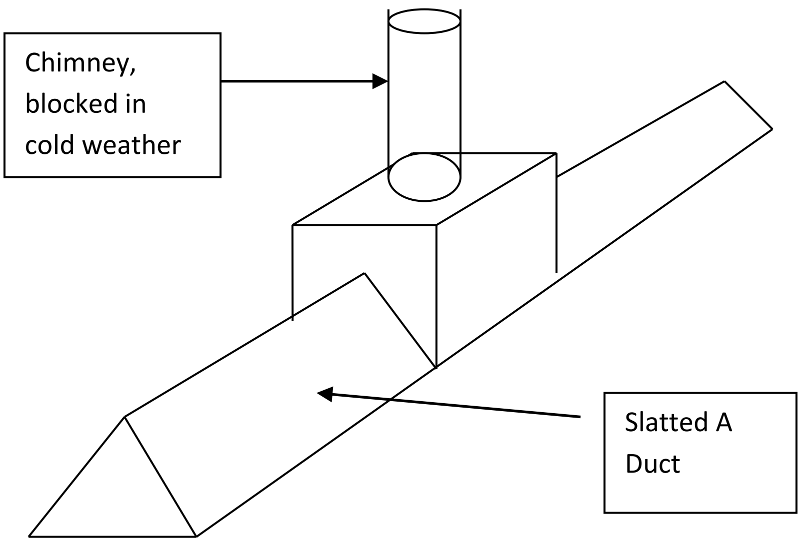
Figure 2 Cross Section with dimensions of A duct





Above the potatoes will be a building similar to the one shown in the photograph on the following page, as there will be considerable snow in the winter. The ventilation of the potatoes could be done by having a chimney as shown in the separate diagram in Photo 2. The chimney would be blocked in cold weather, below 2^{o}C but could be open and allow some air movement in warmer weather up to around 7-0^{o}C. The chimney allows warm air produced by the respiration heat to rise and escape to be replaced by cooler air.

Photo 2 Example of Potato Storage Building and Diagram of Chimney Construction

<table>
<tr><td></td><td>Photograph showing structure above potato store, into which the chimney could enter</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Probably one chimney of similar cross section to the A duct will be sufficient per A duct installed, but if the store is longer than 8m, a second chimney could be installed so that the two chimneys split the duct into even lengths of duct.</td></tr>
</table>

7.3 Training

There are various different options for training which is an essential part of the whole programme.

Specific one day courses on subjects such as cold store management could be carried out by the refrigeration contractors as a requirement of any cold store commissioning involving support from ASF. These one day trainings could be part of "open days" at new interventions. However, it is felt at this stage it is important to underpin the interventions with more wide-ranging training that helps to put the pieces together. The following two options complement each other rather than being exclusive.

One Week Course

A specific one week course carried out on a full time basis in Lahore, Karachi, etc. possibly on the premises of a College or University with the intention that in time that institution could take over the course presentation. These one week course would be targeted at stake holders such as owners, managers, exporters

The course would be on a full time basis (with the expectation the mobile phones would be switched off during the sessions.) An example of the course content and structure could be as follows:

Day	**Timing (Mon – Thurs)** Morning 0930-1100, 1130- 1300 Afternoon 1430-1600, 1630-1800	**Personnel** Two tutors, preferably who have worked together previously
Monday am	Introduction Fresh Produce requirements (to include chilled meat products and frozen products if requested)	Course Tutor (s)
Monday pm	Temperature Handling & packaging including export and disposal requirements	
Tuesday am	Modes of Transport Air, Sea and truck	
Tuesday pm	Visiting speaker from industry	
Wednesday am	Loading procedures, stowage, airflow patterns, stability, ease of loading	

Wednesday pm	Case Studies of whole supply chains, domestic and export	
Thursday am	Visit	
Thursday pm	Energy Usage in supply chain	
Friday am	Packaging (0930-1130) for protection, marketing and disposal	
Friday pm	Monitoring (1400-1600) And feed back	

Course Notes would be provided.

Two Week Course

There could also be a two week course which would be presented in another country, preferably at Writtle College in the UK. This course would be for the larger stakeholders with interest in export and/or larger scale operations and would include a number of visits. The reason for considering Writtle college and the UK is that there is experience in providing these courses and also that visits can be made to examples of the export possibilities in the retail, wholesale and food service sector. An example of course content and structure is as follows:

Day	**Morning**	**Afternoon**
Weekend	ARRIVE AND COLLECTED BY WRITTLE	TAKEN TO PRE-BOOKED ACCOMODATION
Monday	Introduction Quality requirements of fresh produce	First impressions Evaluation of packed and unpacked produce
Tuesday	Visit to supermarket retail outlets	Labeling
Wednesday	Packaging options	Quality evaluation laboratory
Thursday	Visit Dole & Chingford Fruit All day Large scale importers	
Friday	Crop disease damage evaluation, assessment criteria	

	All day (Time allowed for attendance at prayers)	
Weekend	TAKEN TO LONDON AND DROPPED OFF FOR SHOPPING AND SIGHTSEEING	SUNDAY Free
Monday	Transport systems	Hygiene certificate training ?
Tuesday	Visit to packing and washing operation	HACCP training
Wednesday	Pack house operations	HACCP training
Thursday	Visits to be arranged to include wholesale markets All day	
Friday	TBC	Assessment and de-briefing
Saturday	TAKEN TO AIRPORT/LONDON FOR RETURN JOURNEY	

Many activities will involve delegates being divided into groups of 10-15. Course notes will be provided.

(It could be arranged that if the delegates also did some further course work that would be assessed, then the delegates could be awarded some credits towards a University of Essex postgraduate certificate, which could be further built upon as a building brick towards a Master of Science degree if the delegates were interested).

7.4 Refurbishment of Existing Stores

There are various options for refurbishment of existing cold stores, which ranges from a complete change using only the original shell to various levels (packages) of improvement to an existing store. All of these options are considered below.

The main issues in existing cold stores are that they were built for the lowest capital cost with little regard to the running cost. This has given the following situations:

1) <u>Inefficient Refrigeration Systems</u> - the amount of cooling that could be obtained for the same energy input could increase by 40%+ by adoption of new compressors. (Inefficient compressors produce 2.5 kW of cooling for each kW of electricity used; an efficient compressor will produce 3.5-4.0 kW of cooling). Water cooled condensers, as opposed to air cooled condensers, could also help reduce energy usage.

2) Insulation degradation – all insulation deteriorates with time and this is particularly true in cases of uncovered or unprotected thermopore, which has a soft surface that is easily damaged, providing areas for dirt to lodge.

Because of problems with the above, the results are:

3) Infection – the type of construction makes cleaning very difficult even where an industrial vacuum cleaner is available. Disease is normally only visible on the fruit after a few days, such as when the reefer is in transit.

4) Inaccurate control – most basic compressor systems rely on a manual switching on and off which gives, in practice, large temperature fluctuations which is not beneficial for either the product or energy consumption.

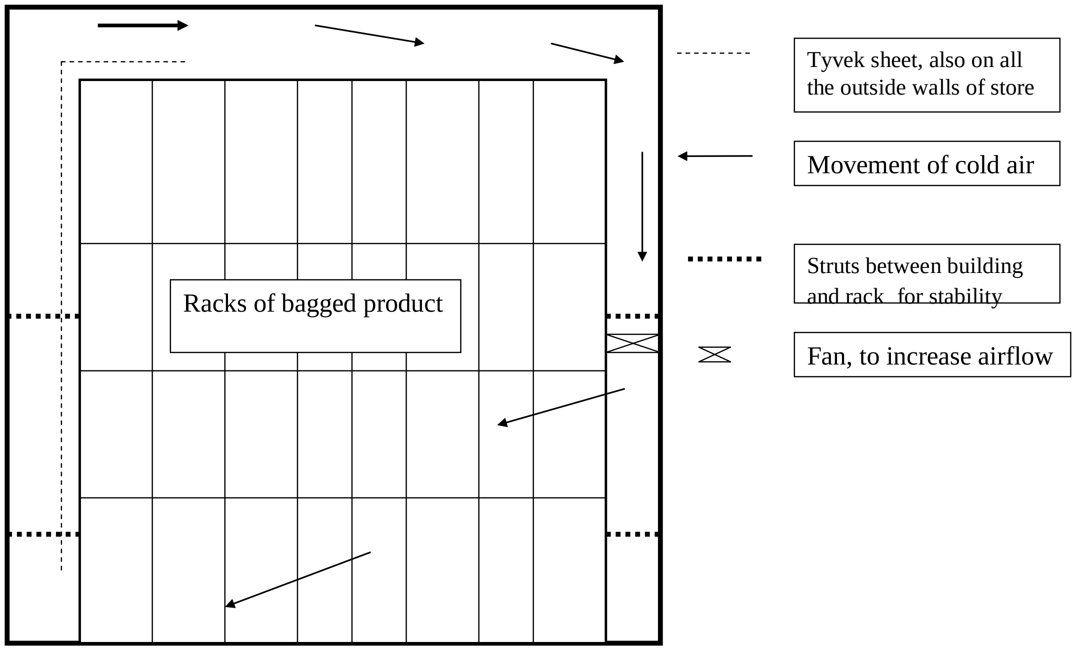
5) Internal temperature variation - the air distribution is poor, relying on cool air falling from the vents at the top of the store which give local "hot spots".

For instance, for a 2750t potato store used for 200 days per year, the energy cost saving of using more efficient equipment is 90,000Rs @15 Rs/unit (some stores are now saying 20 Rs/unit, in which case, the energy cost savings would be 120,000Rs). With very efficient equipment, the figures are 120,000Rs and 155,000Rs, respectively. The cost of the improved equipment is around 500,000 - 600,000 Rs.

Unprotected insulation can be damaged allowing dirt and disease as well as less insulation value; a possible solution could be TYVEK from DuPont (water resistant, easy to clean and does not tear). This would be fixed to the wall and ceiling by either nails then covered or fixed using plastic nails. TYVEK is available in Pakistan and is already in use by ASF on the date project. It costs around 200Rs per/square metre.

Figure 4 is a suggestion of how the airflow could be improved around traditional racked cold stores.

Figure 4 How to Improve Airflow in Racked Cold Stores



7.5 Evaporative Cooling Kit

As stated in the last report the present situation has small farming units with no holding capacity to keep produce even slightly cool for short periods of holding prior to being marketed. Evaporative cooling allows air to pass through a wetted pad, providing an opportunity to hold product at cooler than ambient temperatures and at a high relative humidity which will reduce dehydration or wilting.

The example given previously of air of 28^{o}C and 40% relative humidity (RH) passing through a wetted medium should certainly allow conditions to reach 17.5^{o}C and 90% RH. A reduction of over ten degrees and a change in the rate of moisture loss of about a factor of five could be achieved. Appendix B gives a detailed specification for an evaporative cooling kit. As often seen in the past in many countries, the benefits of evaporative cooling have not been realised owing to the size of different components not being matched. Perhaps this is best illustrated by considering how popular the modern car would be if the petrol tank only provided sufficient fuel for 20 miles before a refill was required.

8 PROPOSED FURTHER STUDIES

The main inputs that are suggested for the future will be building on work performed thus far, unless there are other studies suggested by the meat or dairy sector consultants.

It is suggested that the most important inputs will be:

- Technical assistance with the evaluation of applications,
- Evaluation and assessment of almost completed interventions prior to final commissioning
- Training inputs whether in week long courses or in one day “open days” with new facilities.

9 APPENDIX

9.1 Appendix A Description and Calculations for Cold Store and Cooler

Type -Tunnel Cooler: suggested with a tunnel made of 10 pallets (assuming 500 kg per pallet of crates) with five on each side of a tunnel. The tunnel width should be a minimum of 0.75m.

Fan Size: a single axial fan of 960mm diameter and 960 rpm working against a pressure of 30mm water gauge (300 N/m^2) which will consume around 3.5kW giving 5 m^3 per second (or 10,000 cfm).

Refrigeration unit required the actual efficiency is never close to 100% and using standard figures this will be approximately 70 kW of cooling.

Tunnel Cooler

The tunnel cooler is the most common design for forcing air through product in boxes. Pallet loads of product are placed in two lanes on either side of an open channel. A tarp is placed over the product, covering the open channel, air is sucked from the room through the packed product and down the tunnel and through the fan. The warmed air is directed to evaporator coils, re-cooled and returned to the room. Pallets can be stacked two high to obtain better use of the interior volume of the cooler room. Product in pallet bins can also be cooled with this air management system if bin walls are vented.

This system cools large amounts of product in a single batch without specifically managing the temperature of individual boxes of pallet loads. Many installations can be set up so that each batch has a separate fan. The fan is sometimes fitted with motor-speed control, and, as the return air drops in temperature during the process, the fan is slowed, reducing fan energy use, heat input to the refrigeration system, and possibly product moisture loss.

Cooling Time

Average product temperature during cooling follows a pattern. The rate of temperature drop is related to the temperature difference between the product and the cold air. Product temperature drop per hour is rapid at the beginning of cooling and slows as the product nears final temperature. This process is often approximated with the concept of *half cooling time*, the time required for the product temperature to drop half the difference between the initial product temperature and the temperature of the cold air.

This cooling pattern demonstrated the need to keep cold air close to its set point temperature, especially near the end of cooling. If the refrigerated air temperature rises only a few degrees in the third of four half cooling periods, products may nearly stop cooling. Tunnel coolers should be built as individual rooms or divided into sections so that warm product arriving later in the day will not affect the air temperature near batches that are almost cooled.

Width of Container Stacks for Forced-air Cooling

Wider product stacks increase the distance that cooling air must pass through product. This usually increases the temperature difference between the coolest and warmest product at the end of cooling. If, however, airflow is increased in a wide stack so that air flow per product mass will remain the same, the temperature difference between the warmest and coolest products will be about the same as that for a narrow stack. The static pressure required to move air increases rapidly as stack width is significantly increased.

Coolers for products in containers are usually designed for air to flow across the width of one pallet (maximum pallet width of 1.2m). Therefore a tunnel made of 10 pallets (assuming 500 kg per pallet of crates) with five on each side of a tunnel is suggested. The pallet base will have to be blocked off normally with a piece of sponge and the crates must come right to the edge of the pallets, any air gaps allowing air to pass into the central tunnel without passing through the crates is lost opportunity. The tunnel width should be 0.75m or more wide so as not to have too fast an air speed.

Containers for forced-air Cooling

The packing method and the containers must permit a satisfactory volume of airflow with a reasonable pressure difference across the stack. Packs in which spaces between product are occupied by packing material, such as paper wraps, restrict airflow and slow cooling.

The area of container vent holes should equal at least 5% of the total side panel area. Vent area less than this restricts air flow, causing increased cooling time and increased cooling costs.
Box venting should be designed according to the following:

- Vent size and shape should not allow vents to be blocked by produce
- Use a few large vents instead of many small vents
- Vents should be 1cm wide or greater
- Keep vents 4-7cm from all corners
- Vent area should be 5 percent of the side area.

Refrigeration Capacity

Refrigeration capacity for a forced air cooler is calculated the same as for cold storage. Heat inputs are summed from the following sources: product heat loss; fans and motors; heat loss from packing materials; air infiltration; heat conducted through cold room exterior surfaces; heat input from lights, lift trucks and people; and product respiration. Heat released from the product is great at the beginning of the cooling and drops rapidly during the process. The refrigeration system must be sized to handle the high initial heat release.

A refrigeration capacity of approximately 70 kW of cooling should be adequate. The actual cooling required is close to 35 kW but the actual efficiency of cooling is normally about 50%, which is why 70 kW is suggested for kinnow. The same store design can be used for peaches; but with 50t rather than 60t and a cooling efficiency of 70% with the more vented carton, the total refrigeration capacity is effectively the same.

Calculations

For a store used for kinnow harvested from December- February the calculations and options are as follows:

Consider a kinnow cooling and storage facility for 60 tonne		
Quantity to be cooled at one time	30 tonne	
Ambient and harvest temperature	18°C	
Target temperature	5°C	
Insulation value	0.4 W/°C/m^2	
Suggested size of store	18x12x3 m	
Specific heat of know	3.8 kJ/kg	
Respiration @5 °C	20W/t	
Respiration @18 °C	40W/t	
(50% of store capacity assumed to be at cool temperature)		
cooling rate fast	12hrs	
cooling rate medium	48hrs	
cooling rate slow	144hrs	
heat flow through structure	1.69kW	

infiltration 25%	0.47kW		
mean respiration	0.9kW		
	100% efficiency	70% efficiency	50% efficiency
cooling requirement fast	34.31kW	49.00kW	68.61kW
cooling requirement slow	5.72kW	8.17 kW	11.43kW
cooling requirement medium	17.15kW	24.50kW	34.31kW
electrical heat (estimate)	2 kW		

For the use of peaches the calculations and assumptions are as follows:

Consider a peach cooling and storage facility for 50 tonne		
Quantity to be cooled at one time	25 tonne	
Ambient and harvest temperature	25^{o}C	
Target temperature	3^{o}C	
Insulation value	0.4 W/^{o}C/m^{2}	
Suggested size of store	18x12x3 m	
Specific heat of know	3.8 kJ/kg	
Respiration @3 ^{o}C	12W/t	
Respiration @25 ^{o}C	350W/t	
(50% of store capacity assumed to be at cool temperature)		
cooling rate fast	12hrs	
cooling rate medium	48hrs	
cooling rate slow	144hrs	

heat flow through structure	2.84kW		
infiltration 25%	0.80kW		
mean respiration	4.52kW		
	100% efficiency	70% efficiency	50% efficiency
cooling requirement fast	48.38kW	69.11kW	96.76kW
cooling requirement slow	8.06kW	11.52 kW	16.13kW
cooling requirement medium	24.20kW	34.56kW	48.38kW
electrical heat (estimate)	2 kW		

9.2 Appendix B Evaporative Cooling Kit

The objective is that the farmer receives a kit with all the components that have been sized to work effectively together rather than for the person to get a pump from one person and a "cheap" pump from somewhere else.

Although there could be different sizes of kits it is suggested that the following sizing for a kit could be appropriate:

Component	**Dimensions/Volume Required**
Fan	0.6 m^3/s against 5 mm water gauge (probably 720 rpm)
Pump	0.6 m^3/s against 5 mm water gauge (probably 720 rpm)
Sump tank	20 litres
Header tank	350 litres
Evaporative pad	pad area 0.9 x 1.2m with wood wool 50 mm thick or equivalent (probably held by chicken wire), There will need to be a frame around the pad so aperture dimensions will be 20-40mm bigger
Exhaust louver	Similar size to the wetted pad with free swinging flaps which only open when the air pressure within the room is greater than outside, otherwise should remain closed
Distribution collection pipe	Two one metre lengths of rainwater gutter
Tubing	About 10 m of 20mm outside diameter