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Cold Chain and Postharvest Sector in Pakistan (Final Report)

Cold Chain Interventions (Final Report)

The Agribusiness Project - Agribusiness Support Fund
A company incorporated under section 42 of the companies ordinence 1984.

Cold Chain and Postharvest Sector in Pakistan

Published by The Agribusiness Project, with the funding support of United States Agency for International Development, under Agribusiness Support Fund, Pakistan.

Islamabad, Pakistan

Report Developed By:
Dr. Chris Bishop

Consultant (STTA) - The Agribusiness Project Islamabad, Pakistan

Supervised by:
Aeyesha Gulzar, National Coordinator, The Agribusiness Project

Consultation team:
Value Chain Lead, The Agribusiness Project
Regional Team, The Agribusiness Project
Field team, The Agribusiness Project

Design and Layout by:
EVENEMENT

This report is a live document which can be changed/updated as the project progresses. Any suggestions for further improvement are most welcome.

For more information

Email: info@agribusiness.org.pk, website: www.agribusiness.org.pk

Email: info@asf.org.pk, website: www.asf.org.pk

ACKNOWLEDGEMENTS

This report encapsulates the results of the Cold Chain and Postharvest Sector in Pakistan study undertaken by the USAID Agribusiness Project (TAP). The authors wish to thank all the associated organizations and their project staff for their valuable contributions particularly the TAP value chain leads and the field staff for their tireless efforts spent during the data gathering in the field.

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FOREWORD

A series of Training manuals , Guide Books and Reports have been developed by The Agribusiness Project (TAP) to facilitate the capacity building of farmers involved in TAP's targeted value chains, thereby enabling them to make the requisite transformation from 'subsistence farming' to 'farming as a business enterprise'. The Agribusiness Project is funded by USAID|Pakistan, with the overall goal of supporting improved conditions for broad-based economic growth, enhance profitability and employment opportunities and contributing to poverty alleviation through product and process transformation of selected value chains in horticulture and livestock sub-sectors." The strategy of TAP focuses on:

1. strengthening capacities in horticultural and livestock value chains to increase sales to domestic and foreign markets;

2. strengthening the capacity of smallholders (through farmer enterprise groups-FEGs), individual farmers and agribusinesses to operate effectively and efficiently; and,

3. increasing productivity and profitability through adoption of new techniques and technological innovations (among farmers, agribusinesses and business development services providers).

Through TAP, farmers have been organized as Farmer Enterprise Groups (FEGs) for cultivating the benefits of scale, through optimized production and marketing, and serving as a vehicle for transferring of the benefits of TAP interventions to its stakeholders - the farmers. TAP is providing active support to the FEGs and farmers for improving small producers' positioning in a value chain through support in incorporating producers and their product into stable, profitable market channels, and provision of necessary services and assistance in business development, planning and marketing through inter-linkages. This requires intensive capacity building of the stakeholders placing capacity building at the heart of all interventions.

This report/Manual can be used by anyone involved with the production, cultivation, harvesting and enterprise development training of and for farmers/farmer business groups. The contents have been finalized with the consultation of stakeholders engaged with the value chains.

While these Reports/Manuals/Guide Books are project specific and for a farmer audience, they can also be used for the capacity building of government and non-government agency representatives, processors and exporters who are involved in implementing production/cultivation, enterprise development and value chain programs, through the communities. Finally, I want to thank USAID|Pakistan for funding The Agribusiness Project under which this intellectual capital has been prepared. I would also like to thank ASF for successfully implementing these manuals/guide books across Pakistan for the benefits accrued to the farmers.

Shad Muhammad
Chief of Party
The Agribusiness Project | ASF
Islamabad, Pakistan

THE AGRIBUSINESS SUPPORT FUND

ASF is a 'not-for-profit' company registered under Section 42 of the Companies' Ordinance 1984 with Securities & Exchange Commission of Pakistan (SECP). ASF has extensive experience in strengthening and supporting demand-driven private sector service delivery mechanisms throughout the agribusiness value chain this includes supply inputs, production and export markets ASF aims to achieve this objective by mobilizing angel investment grant provision and technical assistance support of farmer and agribusiness enterprises. The company supports start-ups as well as existing enterprises, enabling them to employ modern technique and practices and build expertise and markets understanding required by a fast-changing economic environment and to improve their productivity, profitability, competitiveness and creditworthiness

THE AGRIBUSINESS PROJECT

The Agribusiness Project is an initiative of the United States Agency for International Development (USAID) and the Agribusiness Support Fund (ASF) Pakistan .the project aims at enhancing competitiveness of agricultural value chains in Pakistan, with a focus on Horticulture and Livestock including dairy, meat and fisheries. The objective of The Agricultural Project is to support and create improved conditions for poverty alleviation. Since Pakistan's economy is agrarian in nature, The Agribusiness Project aims to invest in interventions at the primary, secondary and tertiary levels of production. Under the International Market Access Program (IMAP), the project supports the creations of linkages between exporters and importers. The objective is to facilitate market access and enable trading linkages which translates into agribusiness through trade.

Lists of Acronyms

CA	Controlled Atmosphere Storage
COP	Coefficient of Performance
kW	Kilowatt
PH	Postharvest
PFVA	Pakistani Fruit and Vegetable Association
RH	Relative Humidity

EXECUTIVE SUMMARY

Background

The idea or concept of Cold Chain in Pakistan is not fully understood, and if considered at all, is considered in a fragmentary fashion with broken links rather than as one strong chain. The fact that the Cold Chain needs to start as soon as possible after harvest and be continued without a break through cooling, storage, grading, transport, and finally to the foodservice or retail outlet is a big change for many people who accept a certain level of losses as normal.
The perceived constraints to a good Cold Chain are listed below:

Constraints

1. Four weeks were spent examining every facet of the cold chain, from smallholder producers to the export sector. From all the various stakeholder meetings and visits throughout Pakistan, the main constraints can be summarised as follows: The acceptance of the fact that there are losses and it is just the way it is and nothing needs to be done.
2. Alarming PH losses up to 30-40% which are significant, but these qualitative and quantitative losses were often quoted as normal and sometimes not thought of as an issue.
3. Factors affecting the stability of perishables are not appreciated (temperature, handling, hygiene, humidity).
4. Cold Chain is never considered as one complete chain of activities but rather as a series of isolated operations.
5. Misconception about the cold chain and that it must be kept all the way through, resulting in traditional and fragmented cold chain solutions.
6. Improper use of facilities up to optimum capacity.
7. Inadequate Cold Chain facilities at farm and market level.
8. Lack of technological advancements, even those which do not involve high investment.
9. Shortage and frequent power shut downs.
10. Traditional cold storage having less efficiency and more investments.
11. Lack of expertise for operation and maintenance of Cold Chain facilities.
12. Location of existing infrastructure is questionable.
13. The lack of relating market and production.
14. The lack of appropriate packaging.
15. The lack of will to bring improvement in the existing system.
16. The lack of training.

Interventions

The interventions can be divided into four main objectives:

1) The need to provide clearly demonstrable benefits on the small scale
2) The reduction in the energy input into the Cold Chain
3) Improving the local infrastructure for exports and supply to the supermarket sector,
4) Training in all sectors of the value chain.

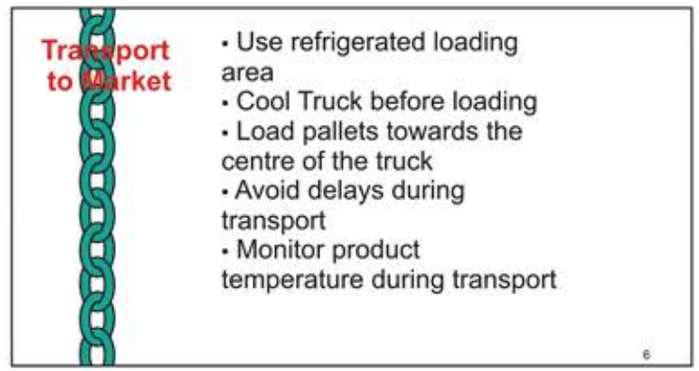
Smallholder training should happen from inception of the project using the Kissan Field Schools (KFS). Training should be provided on farm production systems, for harvesting and placing crops in the shade, careful handling, packaging and economic returns.

The timings of the interventions should be divided into four types; short term or in the next 1-4 months, midterm or within the next 8 months and longer term or within the next year and there will also be cross cutting interventions which will need to start within the next month but will continue through to the end of the project.

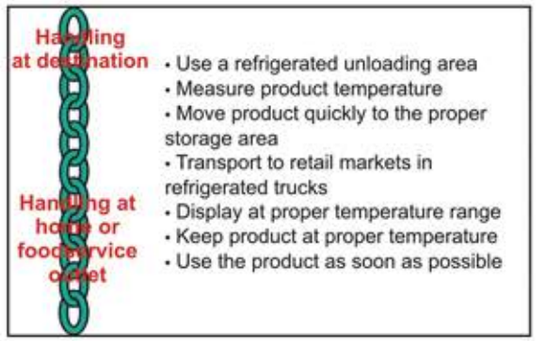
Cold Chain Introduction

Although the expression, cold chain, is frequently used it is seldom fully understood. The parts involved are summarised in the three figures below which have been broken only for clarity but must be considered together.

The importance of not allowing the product to warm in the sun is often overlooked in Pakistan, and the fact that the recently harvested warm crop is losing quality quickly, prior to cooling, means that timeliness as well as resources are needed.



Refrigerated transport is still in its infancy in Pakistan although there are two good local manufacturers who are providing some good examples of good practice although mainly for specific industry sectors like ice cream.



Although the presentation in Mandis left much room for improvement it was encouraging to see the good cool display facilities in the Metro supermarkets.

HORTICULTURAL PRODUCTION IN PAKISTAN

The available statistics are as follows:

Table 1 National Horticulture Production 2009-10

	Production (Metric Tons)
Fruits	6,941,295
Vegetables	6,186,297
Condiments	1,993,894
Total	15,121,486

Source: Ministry of Food and Agriculture, GoP

Of the vegetables approximately 2.5 million metric tons of potatoes were produced and 1.9 million metric tons of onions. The figures for fruit are given in Table 2.

Table 2 Pakistan Fruits Production and Cultivation Areas 2009-10

Ranks	Fruits	Cultivation Area (Hectares)	Production (Metric Tons)	Yield (MT/Hectare)
1	Citrus	198,380	2,150,054	10.84
2	Mango	173,731	1,845,528	10.62
3	Melons	48,214	710,326	14.73
4	Dates	90,584	531,191	5.86
5	Guava	62,052	509,204	8.21
6	Apple	111,597	366,360	3.28
7	Apricot	30,206	193,936	6.42
8	Banana	34,830	154,825	4.45
10	Grapes	15,312	64,729	4.23
11	Plum	6,960	57,470	8.26
12	Peach	15,349	53,994	3.52
13	Pomegranate	13,298	52,381	3.94
14	Ber	5,425	27,950	5.15
15	Persimmon	2,902	23,272	8.02
16	Almond	10,939	21,935	2.01
17	Pear	3,130	20,225	6.46
18	Walnut	1,239	10,838	8.75
19	Loquat	1,504	10,423	6.93
20	Coconut	1,495	9,987	6.68
21	Papaya	1,537	7,932	5.16
22	Jaman	1,228	7,691	6.26
23	Sapodilla (Chikoo)	1,770	6,774	3.83
24	Grewia Fruit (Falsa)	1,270	4,518	3.56
25	Mulberry	639	2,949	4.62
26	Litchi	437	2,862	6.55
27	Cherry	993	1,976	1.99
28	Fig	160	712	4.45
29	Pistachio	197	663	3.37
30	Strawberry	76	270	3.55
31	Others (Kharif+Rabi)	17,068	90,320	5.29
Total		**852,522**	**6,941,295**	**8.14**

Source: Ministry of Food and Agriculture, GoP

Export figures for fruit are given below, with the major vegetable that is exported being potatoes. There are some high value exports by air, which may be only 1000 metric tons a year but have a value of over $1,000 per metric ton.

Table 3 Pakistan- Share of Different Fruits in Exports (2009-10)		
Fruits	**QUANTITY (kg)**	**SHARE**
Kino, Fresh	360,625,046	52.7%
Dates Dried	115,286,231	16.8%
Mangoes	84,921,452	12.4%
Bananas, incl. Plantains, Fresh/Dry	84,488,641	12.3%
Water Melons	13,333,040	1.9%
Dates Fresh	6,394,546	0.9%
Other, Fresh Fruits	5,193,504	0.8%
Other Citrus Fruits Fresh/Dried	3,032,247	0.4%
Other Fruits	11,498,292	1.7%
Source: Ministry of Food and Agriculture, GoP		

Much of the cold storage available is used only for potatoes and was constructed at the lowest capital cost possible, using poor energy inefficient compressors with no backup from generators and insulation, and will degrade with age.

The Outlook for the Future of the Global Fruit and Vegetable Sector

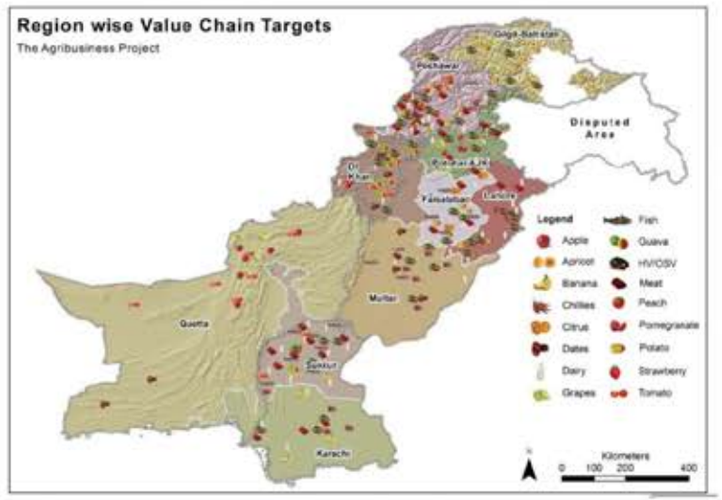
The global market for fruit and vegetables is continuing to grow with an increasing world trade. The location of Pakistan close to the growing markets of the Gulf, combined with relatively low production costs puts the country in a strong position. However, other countries, such as Egypt, have a strong presence, although their present domestic issues make supply more fragmented, so it is an important time to develop Pakistan's agricultural sector with good postharvest practices. At present the prices for Pakistani exports are below the international average, and they are perceived as low quality. It is only by providing uniformly good quality produce that this perception will change. The population of Pakistan is also increasing quickly and needs to be fed, which will require food to be stored and distributed more efficiently.

The Value Chains

USAID Value Chains under consideration

1. Apple
2. Banana
3. Citrus
4. Dates
5. Guava
6. Strawberry
7. Pomegranate
8. Tomato
9. Apricot
10. Chillies
11. Potato
12. Grapes
13. Peach
14. High value/off season vegetables
15. Meat
16. Dairy

(1-14 are considered in this report, while 15-16 have been considered by the STTAs in meat and dairy). Annex 1 provides the best storage conditions for each value chain item.



Constraints Experienced in the Value Chains

Following the visits, meetings, discussions and report reading, the constraints are perceived as the following:

1. The acceptance of the fact that there are losses and it is just the way it is and nothing needs to be done.
2. Alarming PH losses up to 30-40% which are significant, but these qualitative and quantitative losses were often quoted as normal and sometimes not thought of as an issue.
3. Factors affecting the stability of perishables are not appreciated (temperature, handling, hygiene, humidity).
4. Cold Chain is never considered as one complete chain of activities but rather as a series of isolated operations.
5. Misconception about the cold chain and that it must be kept all the way through, resulting in traditional and fragmented cold chain solutions.
6. Improper use of facilities up to optimum capacity.

7. Inadequate Cold Chain facilities at farm and market level.
8. Lack of technological advancements, even those which do not involve high investment.
9. Shortage and frequent power shut downs.
10. Traditional cold storage having less efficiency and more investments.
11. Lack of expertise for operation and maintenance of Cold Chain facilities.
12. Location of existing infrastructure is questionable.
13. The lack of relating market and production.
14. The lack of appropriate packaging.
15. The lack of will to bring improvement in the existing system.
16. The lack of training.

Recommendations and Interventions

The interventions can be divided into four main objectives: 1) the need to provide clearly demonstrable benefits on the small scale, 2) the reduction in the energy input into the Cold Chain, 3) improving the local infrastructure for exports and supply to the supermarket sector and 4) training in all sectors of the value chain.
The cost benefits of various interventions or activities (with assumptions) are given in Annex 10. As mentioned previously in the document, the meat and dairy sectors have been considered in separate consultant reports.

Objective 1. The need to provide clearly demonstrable benefits on a small scale to address the constraints below.

Constraint:
1. The acceptance of the fact that there are losses and it is just the way it is and nothing needs to be done.
2. Alarming PH losses up to 30-40% which are significant but these qualitative and quantitative losses often quoted as normal and sometimes not thought of as an issue.
3. Factors affecting the stability of perishables are not appreciated (temperature, handling, hygiene, humidity).
4. Cold Chain is never considered as one complete chain of activities but rather as a series of isolated operations.
5. Misconception about the Cold Chain and that it must be kept all the way through resulting in traditional and fragmented Cold Chain solutions.
6. Improper use of facilities up to optimum capacity.
7. Inadequate Cold Chain facilities at farm and market level.
8. Lack of technological advancements, even those which do not involve high investment.

Activity 1 A
New Technologies
Pakistan has suffered a period of isolation in respect to developing technologies for Cold Chain. There appears to be a lack of awareness of technologies that could be applied at relatively low capital cost. There appears to be a feeling that if the technology involves a high cost, such as controlled atmosphere (CA) storage, that it will do a better job. Annex 2 provides two examples of recent technologies which have close to a zero capital cost, but lend themselves to the Pakistani systems.

There will be other examples, but it was felt that these two examples, which help to keep apples firm with only refrigerated air storage and whose main benefit is inhibiting disease development, would be good options with which to start.

The timing of this intervention should be cross cutting and so starting as soon as possible and continuing to the end of the project.

Activity 1 B
Mobile Pre-Cooler and Cold Store (for strawberries, peach, apricot, grape, date, guava, pomegranate, tomato, high value off season vegetables)
The present situation has small farming units in high temperatures growing high value products for domestic, national supermarket and export markets. If the product could be cooled at or very close to the field, maintained at temperature until the end of the day, and then possibly transferred to a city cold store, export facility or even supermarket/Mandi, this process would greatly reduce losses and increase quality.
- The facility would work in the rural areas close to the farm and could provide additional employment for women.
- With any facility it should be planned from the outset that training will be given AND there will be an Open Day(s) to demonstrate and promote the technology.
- This is a portable facility so could be taken to various parts of Pakistan for demonstration, or various units could be built. This will not just be relevant in one location.

The specification with calculations and assumptions plus a diagram are given in Annex 3.
The timing of this intervention should be starting as soon as possible

Activity 1 C
Evaporative cooling Kit (for strawberries, peach, apricot, grape, date, guava, pomegranate, tomato, high value off season vegetables)
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, which consists of allowing air to pass through a wetted pad, provides an opportunity to hold product at cooler than ambient temperatures and at a high relative humidity, which will reduce dehydration or wilting.
- For instance, if air of 28oC and 40% relative humidity (RH) passes through a wetted medium, in reality it should certainly be possible to reach conditions of 17.5oC and 90% RH. This creates a reduction of over 10 degrees and a change in the rate of moisture loss of about a factor of five.
- One intervention could be to provide a grant towards an evaporative cooling kit of porous pad, fan, pump, exhaust louver and pipe work, provided that the receiver supply the brick or similar building. It should be stressed that the system does need regular management, such as filling up the water tank from which the pad is wetted.

The specifications with calculations and assumptions plus a diagram are given in Annex 4.
The timing of this intervention should be starting as soon as possible.

Objective 2. The reduction in the energy input into the Cold Chain
Constraints:
9. Shortage and frequent power shut downs.
10. Traditional Cold storage having less efficiency and more investments.
11. Lack of expertise for operation and maintenance of Cold Chain facilities.

Activity 2 D
Refurbishment of existing stores (for apples, potatoes, and citrus)
A high proportion of the refrigerated storage in Pakistan is for apples or potatoes and is based on relatively low capital cost stores of brick and expanded polystyrene insulation with two cylinder ammonia compressors with ammonia as a refrigerant. Unfortunately these systems are not energy efficient, particularly when ambient temperatures can exceed 40oC and storage periods of over 200 days. The use of solar panels should be considered for the production of electricity to run at least some of the refrigeration system. Annex 5 gives a summary of the benefits of refurbishment of cold stores. Any change of materials or machinery should be taken in conjunction with additional training, which is considered in Annex 7.
The timing of this intervention is that a start within the next four months should be considered.

Activity 2 E
Natural ventilated storage (for potatoes)
Energy usage is important, and there must be greater consideration over how energy usage can be reduced, such as with activities C and D, or in situations where the energy usage can be reduced to zero.

The potato is produced in all ecological areas of Gilgit-Baltistan and is an important cash crop. At present the yields are low and this can be partly attributed to poor storage of seed and the lack of good returns due to postharvest losses. An improvement in storage is important. There are various options for improving the storage regimes, including the provision of controlled atmosphere stores (CA) for which the consultant cannot see the logic. A better option would be to use naturally ventilated stores that are described in Annex 6, which would reduce energy usage, be low cost and constructed from readily available local materials.

The timing of this intervention is starting as soon as possible.

Objective 3. Improving the local infrastructure for exports and supply to the supermarket sector
Constraints
12 Location of existing infrastructure is questionable.
13 The lack of relating market and production.
14 The lack of appropriate packaging.

Activity 3 G
Construction of ripening unit near Mandi or supermarket (for bananas and stone fruit)
When transported in the ripe stage, various fruit are much more likely to be damaged and also have a short shelf life. The idea would be to have a small (6-10t) ripening unit, in a city like Lahore, using ethylene which could be used for bananas but also other fruit such as peaches and mangoes. This would be similar in size to a marine container but with a larger fan and cooling capacity plus an ethylene generator as opposed to the more dangerous acetylene (since the initiation of this consultancy there has been at least one death in Beirut where acetylene was used in a ripening room). Annex 8 provides a suggested specification for the ripening unit.

The timing of this intervention is that it should start within the next eight months.

Activity 3H
Assembly cold store Karachi (for citrus)
At present there are very limited facilities for final grading and loading of marine refrigerated containers near Karachi's port, resulting in opportunities being missed. There is interest in having a small holding facility which would be used by PFVA members. There is an existing site of MK Enterprises which has an open warehouse for cold store and grading, it is a good site where no land preparation would be needed. At present there are two un-shaded refrigerated marine containers. Annex 9 provides a suggested specification for the assembly cold store.

The timing of this intervention is that it should start within the next four months.

Objective 4. Training in all sectors of the value chain
Constraints:
15. Lack of will to bring improvement in the existing system.
16. The lack of training.
Training is at the heart of the project and comes in various formats. The project is about innovation, which requires intensive training, formal trainings, hands on technical assistance, exposure visits, organizational trainings, demand driven trainings and refresher trainings.

Activity 4 F
Training
An example of a suggested two week external training which covers a number of different formats of training is given in Annex 7.

The timing of this intervention is that it should start as soon as possible and continue through to the end of the project.

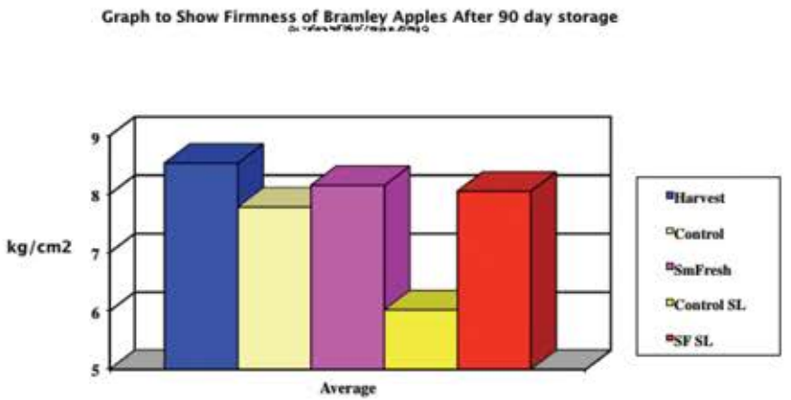
Annexes

Annex 1. Store Conditions for Value Chain Products

Product	Storage Temperature °C (°F)	Ethylene production	Ethylene Sensitivity	Respiration Rate	Approx post harvest life	Comments
Apple	-1(30) to 4(40)	VH	H	L	1-6 months	Very variety dependent
Banana	13-15 (55-59)	M	H	L	1-4 weeks	Variety differences, stores in green condition
Citrus (pummelo)	7-9 (45-48)			L	12 weeks	Examples of varieties
Citrus (tangerine)	4-7 (40-45)	VL	M	L	2-4 weeks	
Dates	-18 to 0 (0-32)	VL	L	L	6-12 months	RH of 75% as opposed to 95% for most products
Guava	5-10 (41-50)	L	M	M	2-3 weeks	
Strawberry	0-2 (32-35)	L	L	L	7-10 days	Very variety variable
Pomegranate	5 (41)			L	2-3 months	
Tomato	8-10 (46-50)	H	M	L	1-3 weeks	Very variety dependent (can store for 6 weeks), green very sensitive to ethylene
Apricot	-0.5 to 0 (31-32)	M	M	L	1-3 weeks	
Chillies	5-10 (41-50)	L	M	varies	2-3 weeks	85-95% RH
Potato	4-11 (40-52)	VL	M	L	5-10 months	Storage temperature depends on variety and end market
Grape	-1 to 0 (30-32)	VL	L	L	1-3 months	Variety dependent, some varieties store well
Peach	-0.5 to 0 (31-32)	H	M	L	1-3 weeks	Temperatures of 4-7°C should be avoided as this gives floury texture to fruit
High value /off season vegetables						
Carrot	0 (32)	VL	H	M	6 months	
Broccoli	0 (32)	VL	H	M	10-14d	
Capsicum	7-10 (45-50)	L	L	L	2-3 weeks	
Meat or fish frozen	-18 or lower				Long periods	
Meat chilled	-1.5 to 0 (29 to 32)				30 days, 70 days packaged	No ventilation
Veg. frozen	-18 or lower				Long periods	

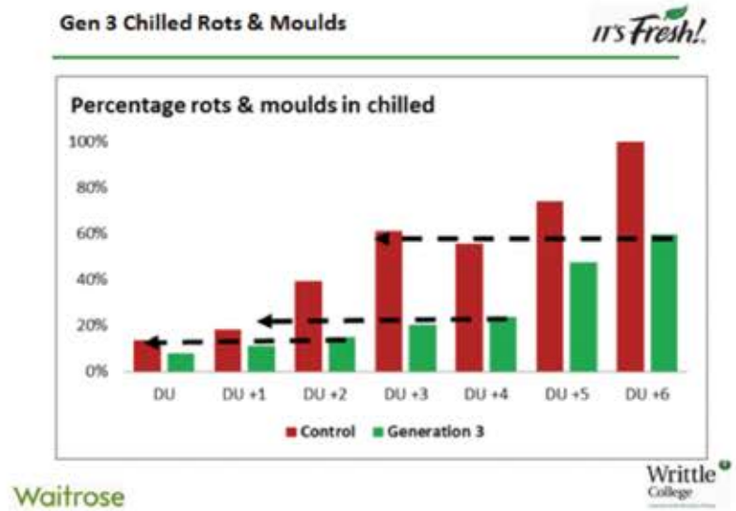
Annex 2. Interventions – New Technologies

The two suggested technologies that in particular should be considered for interventions are:
1. MCP (trade name Smartfresh, company Agrofresh)
This is a chemical which is applied in a gaseous form in a sealed store as soon after harvest as possible. The chemical comes in a tablet or powder form and is placed in a bucket with water, ideally with agitation, with the powder reacting with the water to produce 1-MCP which acts with the ethylene binding sites of the fruit so as to reduce respiration and the ripening (ageing) effect of ethylene. This means the crop can be kept for longer in cold conditions without investing in high capital cost and technically complex control atmosphere storage. This result is probably more important in Pakistani conditions since the fruit will stay firm for longer once removed from the cold store. The bar chart below illustrates where there is a sharp reduction in firmness in untreated fruit after seven days at 20oC compared to a small reduction with the treated fruit.



There will be issues with registration for the use of this chemical which has been passed for use in many countries such as USA, Australia, New Zealand, EU, India and South Africa. There will not be difficulties with carrying out trials. The product works on almost every variety of apples but there are exceptions such as Braeburn.
The first contact with the company should be with Nathalie Gocha (Tel +33 1 58690254 1; Cell: + 33 6 07 53 31 0223; and email ngocha@agrofresh.com).

It's Fresh (trade name of Food Freshness Technology)
This technology is described as ethylene absorbing strips but the technology acts to inhibit rots and diseases and so extend shelf life. It should be emphasized that the technology inhibits rots and disease but does not eliminate them. An example of results between the strip (called generation 3) and nothing (the control) on strawberries for a UK supermarket is given below:



The strips can either be used on a retail pack or as a larger strip on a whole carton. The strips are put in by hand so there is no investment in application equipment. The strips look similar to a postage stamp.
The first contact with the company should be with Simon Lee (Tel: +44 (0) 1675 431001; Cell +44 (0) 7770 934005; Email: simon.lee@foodfreshnesstechnology.com).

Annex 3. Interventions – Mobile Pre-Cooler

Mobile Pre-cooler and store for 1000kg cooling and 2500kg cooled
Specifications:

- Length 4.8m, width 1.95m, height 1.95m of frame construction with 100mm polyurethane panels on sides, roof and base.
- Door of similar insulation quality of the "butcher's door" type with high quality rubber gasket and plastic strips to reduce air interchange
- Cooling unit capable of giving 6.5 kW of cooling (evaporator to have a TD of 5oC or less)
- Refrigerant not specified
- Additional fan to provide forced cooling of 0.5m3/s against a water gauge of 10mm.
- Single phase operation
- Single phase generator to provide power for the above if required

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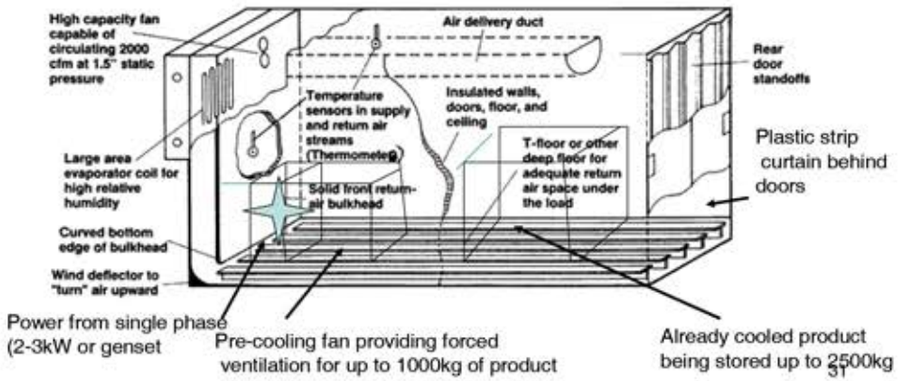
- Refrigerant not specified
- Additional fan to provide forced cooling of 0.5m3/s against a water gauge of 10mm.
- Single phase operation
- Single phase generator to provide power for the above if required

	Panel insulation with 100mm panels (U)						0.248	W/m2/deg C
Target temperature		*					10	Deg C
Flesh temperature		*					30	Deg C
Ambient temperature		*					40	Deg C
rate of cooling							6	Hrs
dimensions of unit (external)								
Height							1.95	M
Width							1.95	M
Length							4.8	M
internal dimensions							1.75	M
Width							1.75	M

Length							3.8	M
assume peaches								
quantity to be cooled in time							1000	Kg
holding quantity at temperature							2500	Kg
heat prod in Watt at cool temp							59.88024	W
heat prod in watts at warm temp							419.1617	W
Heat flow through structure (external dimensions								
surface area							45.045	m2
TD							30	deg C
U							0.248	W/m2/deg C
total heat flow							335.1348	W
Respiration heat of product at temperature							149.7006	W
respiration heat of product cooling (average)							179.6407	W
Heat air leakage (assumed 2 empty volumes/hr)*								
internal volume							11.6375	m3
TD							30	deg C
Sp ht of air per cubic metre							1.3	Kj/m3
air exchange							2	Vol
							907.725	W
Cooling Load								

mass to cool							1000	Kg
time to cool							21600	S
sp ht of product							3.8	kJ/kg
temp reduction							20	deg C
							3.518519	kW
							3518.519	W
Fan power and lights (estimate)			*				750	W
TOTAL COOLING REQUIRED								
Through structure, Through air leakage, Through respiration, Through cooling								
							5840.72	W
Allow 10% safety factor							584.072	W
TOTAL COOLING REQUIRED							6424.792	W
with a COP of just over 3			*				2	kW

B.- Sketch of Pre-Cooler and Cold store (on a trailer not shown) dimensions 4.80x1.95x1.95m (16x6.5x6.5 ft) To operate in the shade NOT full sun



Note: Although the diagram shows the container with a T bar floor, this is not necessary and a standard non slip floor used in a cold truck would be adequate.

Annex 4. Interventions – Evaporator Cooling Kit

Evaporator cooling kit to be installed in a provided brick building of approximate dimensions of 3 x 5m with a height of 2m and a thatched roof or equivalent. The building should have no other openings apart for the door, wetted pad and louver.

Specifications:

- Fan: 0.6 m3/s against 5 mm water gauge (probably 720 rpm)

- Pump: Capable of delivering 1 litre per minute against a head of 2.5m. The pump should be in a small sump tank of approximately 20 litres.

- Wetted pad: Area 0.9 x 1.2m with wood wool 50 mm thick or equivalent (probably held by chicken wire). (Please note this is the pad size so with the frame it will be about 20-40mm wider and higher.)

- 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.

- Pipe work: Suggested hose with outside diameter of around 20 mm, but what is available should be fine. (valve on the pipe between header tank and wetted pad to alter flow. The water distribution above the wetted pad can be done by having 1.m of rain gutter with small holes drilled in the base. The water collection can be using some guttering below the pad at a slight angle so the water flows into a sump from where the water is pumped up into the header tank.

- Header tank: Capacity 350 litres+ (sufficient water for one day)

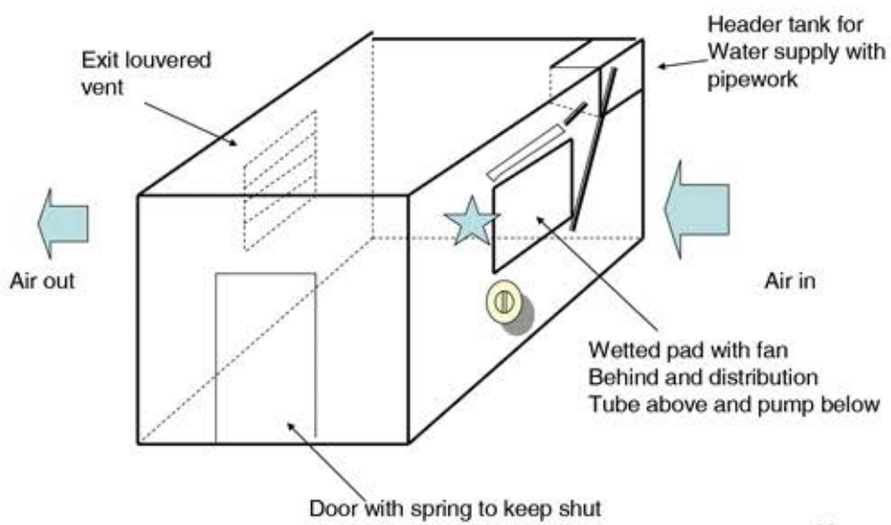
THIS WILL NEED TO BE FILLED DAILY

- Door spring: Ensures that the door remains shut when not being used.

Assumptions are starred *

	Consider an evaporator kit				
	Sizing				
	Conditions outside				
	Temp	30	deg C	*	
	RH	30	%	*	
	Enthalpy	50	kJ/kg		
	water content	0.008	kg/kg		
	Conditions after pad				
	Temp	20	deg C		
	RH	90	%		
	water content	0.012	kg/kg		
	If air speed is	0.5	m/s		
	Pad area	1.2	m2	(0.9 x 1.3)	
	Airflow	0.6	m3/s		
	mass of air	0.72	kg/s		
	water required per second	0.00288	kg		
	water required per minute	0.1728	kg		
	assuming 3 times as much water should be pumped to maintain a wetted surface				
	pump flow	0.5184	l/min		

C.- Evaporation cooling Layout



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Annex 5. Interventions - Refurbishment of Existing Stores

The two factors that particularly affect the energy usage in cold stores are the insulation and the machinery efficiency. The calculation given below considers putting panels on the walls of an existing 2500 metric ton potato store, and so replacing the existing brick which absorbs solar radiation which will be reflected by the white, non-matte panels.

The COP (coefficient of performance) of the refrigeration equipment, which is a measurement of its "efficiency" is given for two options for what should be achieved with typical equipment (2.5) and what should be achieved with better equipment (3.5).

Pakistan typical potato store						
						Thermal resistance
Brick	0.45	m		0.81		0.555556
Thermopore	0.1	m	(polystyrene)	0.037		2.702703
wall thermal resistance						0.176
						3.434258
			U	value		0.291184
assuming a 30% degradation over 10 years						
Brick	0.45	m		0.81		0.555556
Thermopore	0.1	m	(polystyrene)	0.1		1
wall thermal resistance						0.176
						1.731556
						0.577515
Panel						
polyurethane	0.1	m	0.026		3.846154	
					0.176	
					4.022154	
			U	value	0.248623	
Assume 2500t cold store in Pakistan (100,000bags?)						2500
Volume at 2.25 cubic metres per t					5625	cubic metres
Assume height of 7m (23 ft)					803.5714	sq metres
assume square					28.34734	M
Wall area					793.7254	sq metres

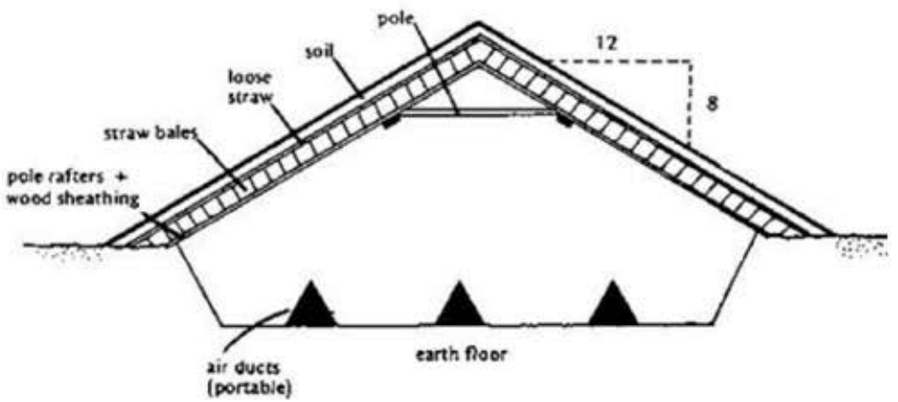
If store at	5	deg C				
ambient	60	deg C	(solar heat gain)			
ambient	35		shaded			
Heat flow with traditional insulation 5 years old					25211.38	W
Heat flow with panels		(shaded)			5920.152	W
This is	difference				19291.22	W
Assuming a COP		2.5			7.716489	kW
At	15	Rs/unit			2777.936	Rs per day
assuming	200	day storage			555587.2	Rs per year
		biggest difference				
Assuming COP		3.5		5.511778		
	15	Rs/unit		1984.24	per day	
				396848	per year	

Annex 6. Interventions - Natural Ventilated Potato Storage

The potato is produced in all ecological areas of Gilgit-Baltistan and is an important cash crop. At present the yields are low and this can be partly attributed to poor storage of seed and the lack of good returns due to postharvest losses.

Although a more precise design would depend very much on climatic data from Gilgit-Baltistan, the basic concept involves having the potatoes to be stored in a pit dug about 3m into the ground with a well drained 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.

A possible design is shown below. As stated previously the actual sizing of the component will depend on location with its temperature variability. In practice the design may involve only one air duct rather than three and this will depend on the length and desired capacity.



Annex 7. Interventions – Training

The innovation and interventions will require consistent inputs of intensive training which are necessary at different levels, from half day on farm demonstrations to the more detailed view for decision makes of the various stakeholders.

It is thought that the most effective training for the decision makers of the various stakeholders would be "off site" so as to reduce the level of external distraction and probably closely connected with market awareness activities. The example is for Writtle College, UK from where the consultant also works. A Muslim member of Writtle staff had a meeting with Mr. Shafqat Syed from the Pakistani team at Fruit Logistica in Berlin in early February to discuss any cultural issues. The College has Halal meat, a prayer room, etc., as regular facilities.

An example of a possible two week course is given below:

- Modes of transport- air , sea, truck (in particular the final one needs to include specific case studies)
- Crop requirements- pre-cooling, temperature, ethylene, damage prevention
- Logistics awareness (just an awareness) – basic logistics theory and awareness of paperwork
- Pre-cooling- Cold store management and energy usage
- Loading procedures
- Quality requirements- hygiene, CSR and certification (this would include doing the half day Public Health Certificate level 2)
- Visits to example facilities, importers, wholesale markets, etc.
- Speakers from the industry (both technical and commercial)

General Comments

- The intention is to have the delegates (ideally 10 -14) would arrive one week-end and then would have two weeks of training with the mid week-end left free for tourist visits or visiting relations, etc.
- A draft timetable for the two week course would be emailed at least one week prior to the course.
- The course would preferably be residential with some evening activities.
- All delegates would have to write a two-page report on a minimum of two visits as a requirement of receiving an attendance certificate.
- Copies of the hand-outs of the theory sessions would be emailed to Pakistan prior to the course.
- Transport would be provided to and from the local mosque for Friday prayers.

Annex 8. Interventions – Small Ripening Unit

The objective of this ripening unit is to provide even ripened product for local market, meaning that product can be transported in an unripe state when it is more robust.
The important factors are even temperature and gas concentration, and these will be achieved with correct airflow, refrigeration and ethylene generation.
The most common fruit will be bananas, but mangoes are another example.

Specifications:

- Ethylene generator capable of providing 100 ppm
- Length 6m, width 2.5m, height 2.5m with 100mm polyurethane panels on sides, roof and base.
- Door of similar insulation quality of the "butcher's door" type with high quality rubber gasket and plastic strips to reduce air interchange
- Cooling unit capable of giving 6.5 kW of cooling (evaporator to have a TD of 5oC or less)
- Refrigerant not specified
- Additional fan to provide forced cooling of 1.0m3/s against a water gauge of 15mm.
- Single phase operation
- Single phase generator to provide power for the above if required

The precise layout may depend on the cartons used, but it is essential that there is forced ventilation to provide even temperature and gas concentration throughout.
Mode of operation:

- Day 1 "green" product loaded so as to allow airflow and cooled to an even temperature of 13.5oC
- Day 2 Ethylene applied from generator and temperature allowed to rise to 17oC
- Day 3 Ethylene generator switched off and product inspected, temperature maintained at 17oC
- Day 4 product inspected, temperature maintained at 17oC
- Day 5 product inspected and probably removed for market, if not maintained at 17oC

The whole process can be speeded up by increasing the temperature by two degrees but this does give the higher possibility of uneven ripening.

Annex 9. Interventions - Assembly Cold Store Karachi

The product in grading and inspection should then be packed in the correct cartons for export and palletized and all products in the store should be on pallets which will then be loaded into marine containers. The total capacity of the store is that of three marine containers with the capacity for 10t of this to be force cooled at any one time.
The product will be moved around on pallets using a hand operated pump truck. The height of the store is such as to take one pallets loaded to the correct height for a marine container and allow for airflow.

Specifications:

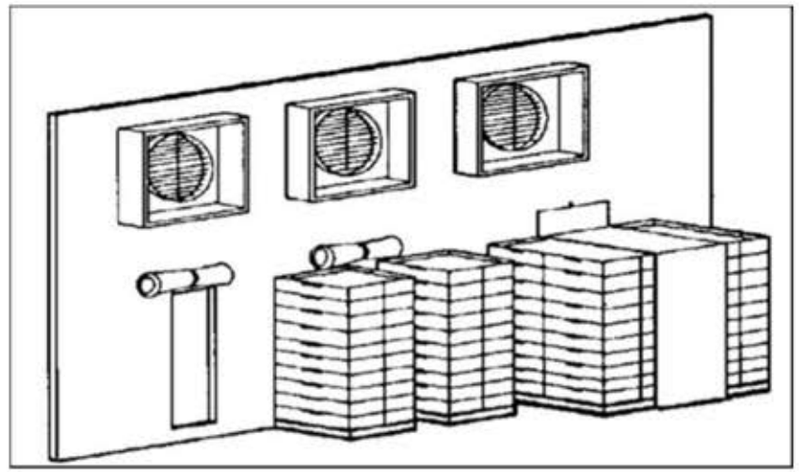
- Length 8.0 m, width 10.0m, height 3.0 m of frame construction with 100mm polyurethane panels on sides, roof and base.
- Door of similar insulation quality of the "sliding door" type with high quality rubber gasket and plastic strips to reduce air interchange
- Cooling unit capable of giving 43 kW of cooling (evaporator to have a TD of 5oC or less)
- Refrigerant not specified
- Additional fan to provide forced cooling of 1.5m3/s against a water gauge of 15-20mm.
- Three phase operation
- Three phase generator to provide power for the above if required

Assumptions and Calculations:

Karachi Export Store							
	External Temperature			35			deg C
	Internal Temperature			7			deg C
	to store less cooling			50			t
	Height			3			m
	Width			10			m
	Length			8			m
	Cooling capacity to cool			10000			kg

	in			36000			secs
	Thermal capacity of product			3.6			kj/kg/deg C
	starting respiration rate			119.7605			w/t
	Holding respiration rate			29.94012			w/t
	Insulation level of structure			0.25			w/m2/deg C
	NO SOLAR HEAT GAIN						
	Infiltration rate			1			Air volume/hr
	Cooling requirement						
					28		kW
	Heat flow through the structure						
	Area					268	m2
					1.876		kW
	Heat flow through leakage				2.912		kW
	Respiration				1.497006		kW
					0.748503		W
	fan power etc assumed				4		kW
	Total cooling required				39.03351		kW
		10% safety factor			3.903351		

	TOTAL LOAD			42.93686		kW



Sketch of a cooling wall for forced cooling of product, the air is sucked through the cartons and then blown back into the room through the fans. For this case two openings rather than three are suggested.

Annex 10. Costs and Benefits Estimate

Intervention	Estimated Cost Laks Rs	Benefit per year	Estimated usage days	Example Crop & field value
Mobile cooling Unit	18	8	40	Strawberries 150 Rs/kg
Mobile cooling Unit	18	10	60	Peaches 40 Rs/kg
The price of equipment is based on estimate given by KoldKraft for the mobile cooler. The number of days of usage is based on the assumption of harvesting for 10 days at four locations with strawberries and for 15 days at four locations for peaches. The running costs are based on 12 hours at 15 Rs/kWh with 2 kW power requirement reducing losses reduced for strawberries from 50% to 40% assuming a throughput of 3.5 metric tons per day. The losses for peaches are assumed to reduce by 10% assuming a throughput of 6 metric tons per day. Labour and management charges included				
Evaporative cooling	2	0.6	50	High value veg 40 Rs/kg
Equipment costs installed with a reduction of weight loss of 6% (giving 5% more to sell) with 3 metric tons stored				
Store Improvement	32	9 (on wall insulation)	Full season	Potatoes 8 Rs/kg
Reduction in electrical running costs and also reduction of losses. The information on the reduction of running costs is included in Annex 5				
"cellar" stores	2	0.8	Full season	Potatoes 8 Rs/kg
Estimation of costs from similar arrangements from other parts of the world with a discussion on local material costs. The loss reduction is estimated as 20% more crop to sell in a 50 metric ton store				

Annex 11. People Met

This list is not exhaustive but people and organisations met include:

- Mr. Mohammad Iqbal ex PHDEC,
- Mr. Farrukh Baig Mirza COP (PACCD)
- Mr. Rafique potato grower and store owner
- Mr. Lawrence Harrison CEO KoldKraft, refrigeration manufacturers,
- Mr. Shamoon Sadiq, consultant
- Prof. Malik University of Faisalabad (discussion on phone)
- Mr. Rahil Mahtab F&V buyer Metro stores
- Mr. Abid Bukhari, Consultant, formerly with Pepsi Co
- Mr. Malik, CEO of Sunny Enterprises, and other KPK stakeholders
- Mohammad Ilyas Khan, Secretary General and various members of the Fruit and Vegetable Exporters Association
- Bilal Traders
- Mr. Abdul Wahid. Potato packer and store owner
- Fish freezer and exporter (Diamond Exports)
- MK Enterprises
- Mr. Malik CEO Agility Logistics
- Staff of the Institute of Business Administration
- Mr. Hamid, CEO of Koldware refrigeration manufacturers

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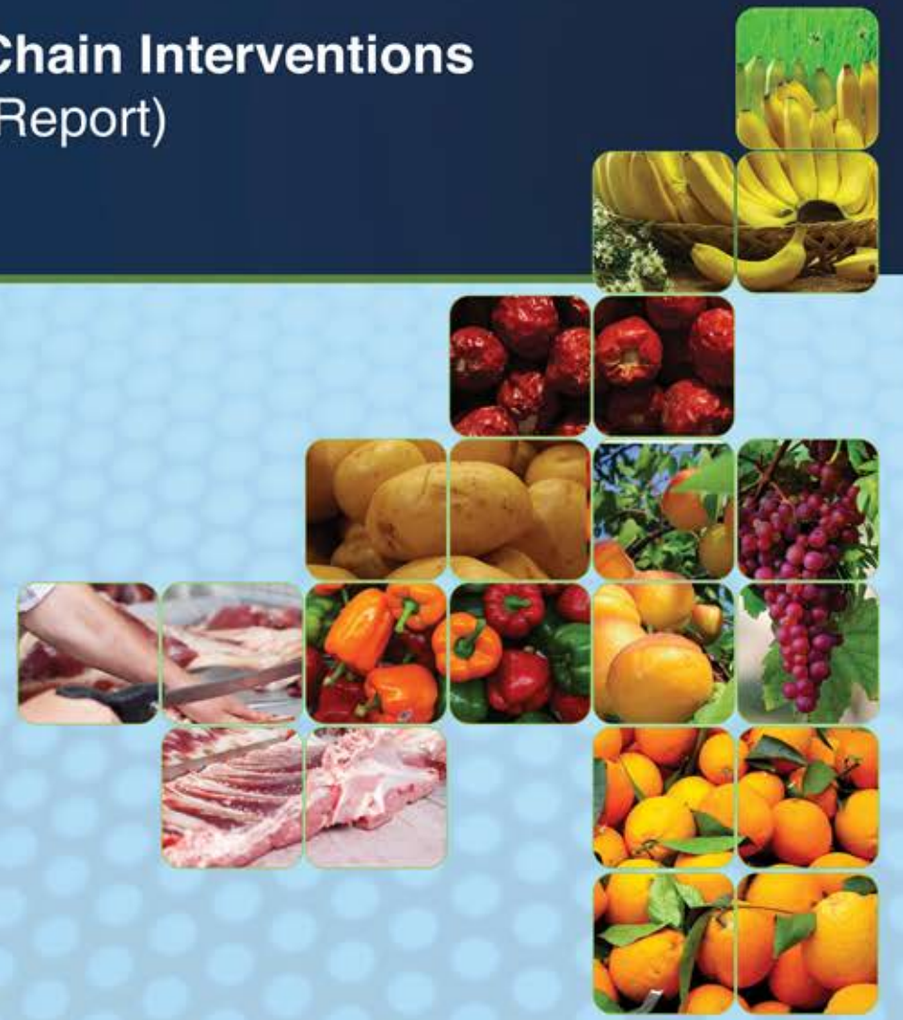
Cold Chain Interventions
(Final Report)



The Agribusiness Project - Agribusiness Support Fund
A company incorporated under section 42 of the companies ordinence 1984.

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**
1. Devalued rupee provides good export opportunities for both fresh produce and value added (such as potato crisps) 2. Availability of good arable land and rain fed irrigation 3. 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**
1 Low costs in the market place 2 Programmes such as ASF to give impetus to development	1. Security situation 2. 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 18oC for kinnow and 25oC 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 5oC for kinnow and 3oC 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

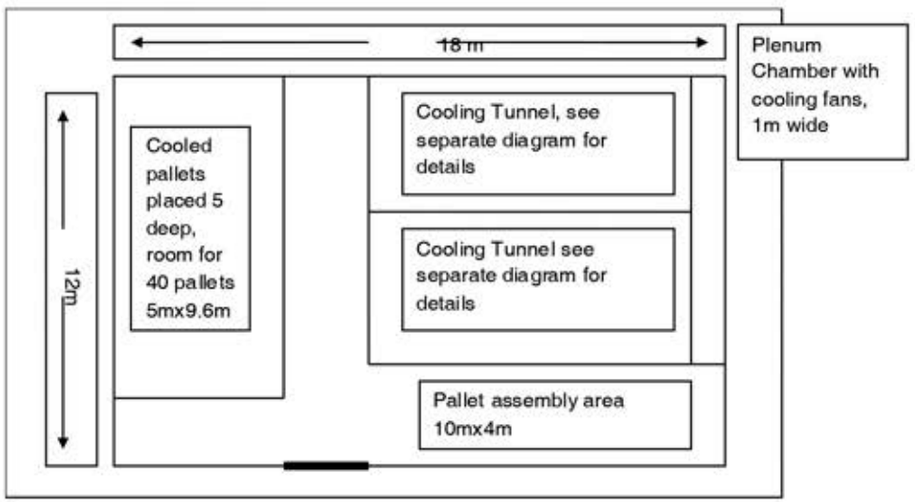
Another example of cartons with small vents

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.

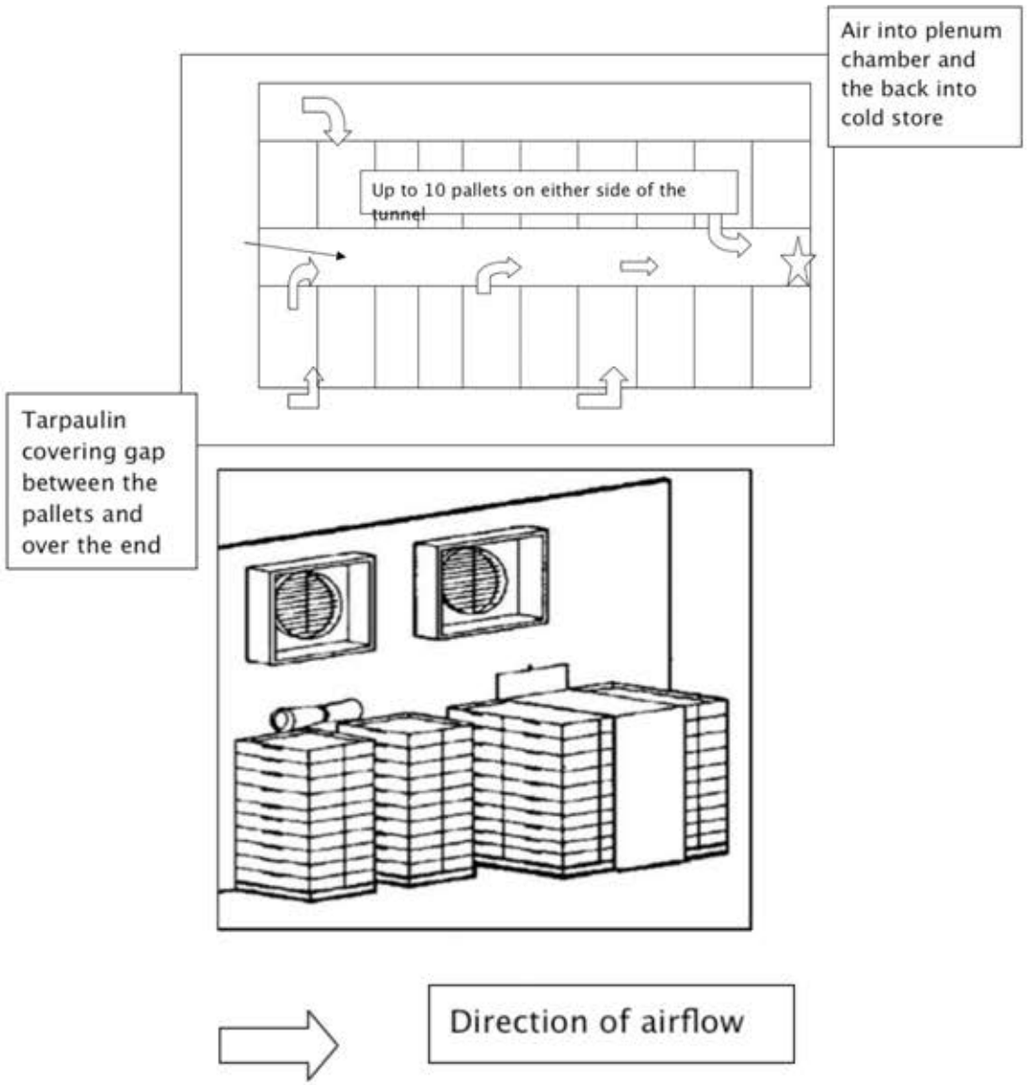
Figure 1 Sketch of Layout for the Cold Store and Cooling Unit

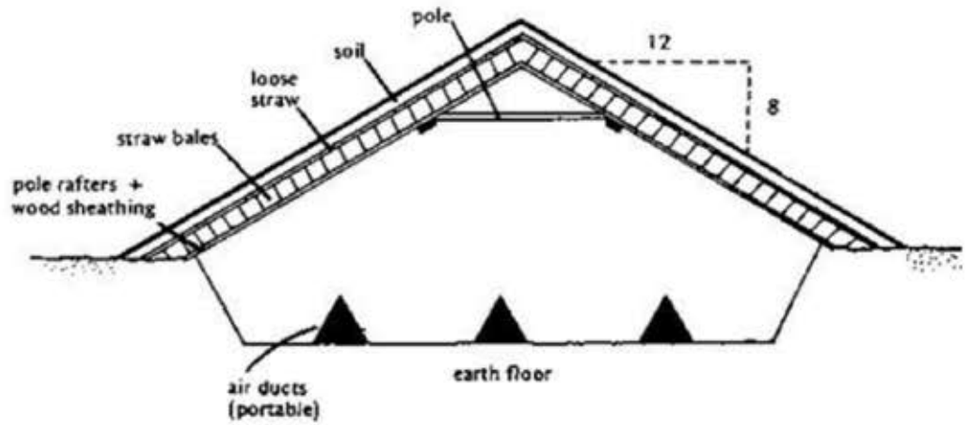


Space for 60 pallets (1.2 x 1.0m) each with 750kg stacked in cartons. A pump truck will be required for moving the pallets around.

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.

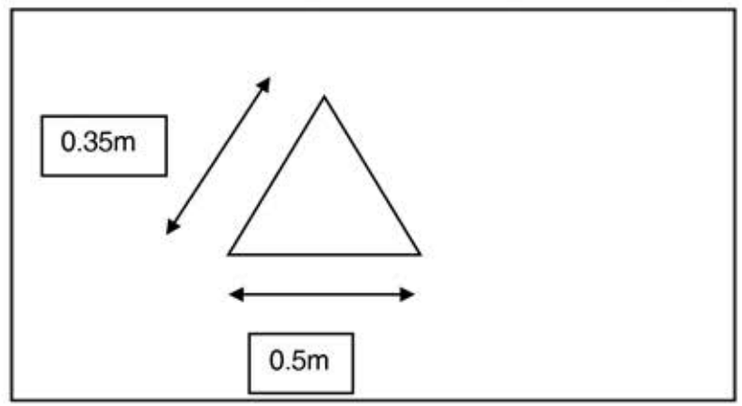
Following pallet assembly, the pallets would be placed so as to form the cooling tunnel. Therefore all carton vents need to be line with the intended airflow. The tunnel can start cooling with only two pallets. Once the pallets have been cooled they can be moved to the other side of the cold store.

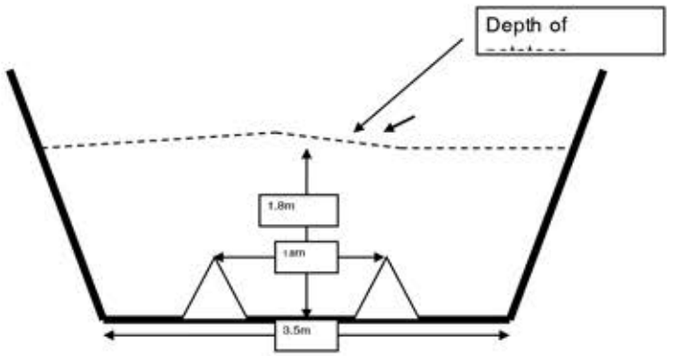




- Possible dimensions for 25t
- Width 3.5m, depth of potatoes 1.8m, length 6m
- Two "A" ducts to be placed in the base with a distance of 1.8m between them. The dimensions of the ducts to be such as to give 0.5m base and side of 0.35m, probably made of wood with slatted sides or could be made with strong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

Figure 2 Cross Section with dimensions of A duct

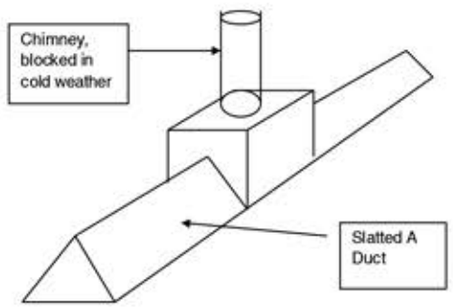




Above the potatoes will be a building similar to the one shown in the photograph on the following page, as there will be considerable snow in the winter. The ventilation of the potatoes could be done by having a chimney as shown in the separate diagram in Photo 2. The chimney would be blocked in cold weather, below 2oC but could be open and allow some air movement in warmer weather up to around 7-0oC. 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

Photograph showing structure above potato store, into which the chimney could enter



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.

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	

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	

(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:

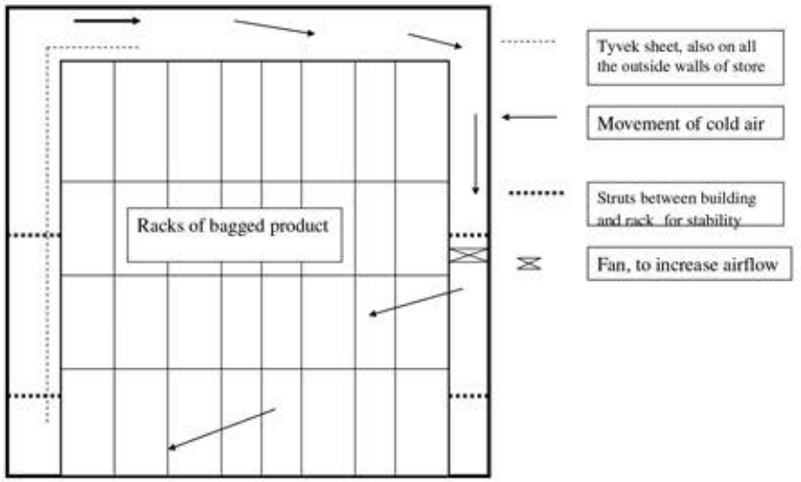
1) Inefficient Refrigeration Systems - the amount of cooling that could be obtained for the same energy input could increase by 40%+ by adoption of new compressors. (Inefficient compressors produce 2.5 kW of cooling for each kW of electricity used; an efficient compressor will produce 3.5-4.0 kW of cooling). 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.



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 28oC and 40% relative humidity (RH) passing through a wetted medium should certainly allow conditions to reach 17.5oC 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/m2) which will consume around 3.5kW giving 5 m3 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.

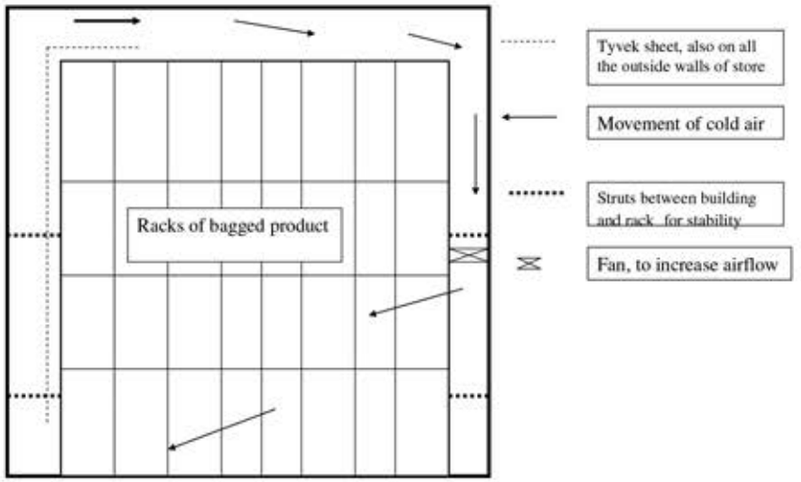
Cooling Time

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.



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9 APPENDIX

9.1 Appendix A Description and Calculations for Cold Store and Cooler

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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.

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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		

Consider a peach cooling and storage facility for 50 tonne			
Quantity to be cooled at one time	25 tonne		
Ambient and harvest temperature	25°C		
Target temperature	3°C		
Insulation value	0.4 W/°C/m²		
Suggested size of store	18x12x3 m		
Specific heat of know	3.8 kJ/kg		
Respiration @3 °C	12W/t		
Respiration @25 °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 m³/s against 5 mm water gauge (probably 720 rpm)
Pump	0.6 m³/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

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