The Agribusiness Project (TAP)

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

Cold Chain and Postharvest Sector in Pakistan
Final Report
for the Agribusiness Project

Prepared by: Dr. Chris Bishop

Independent Consultant to CNFA
Writtle College, Chelmsford,
Essex CM1 3RR
United Kingdom

February 22, 2013

Submitted to:

CNFA, Inc.
1828 L Street, NW, Suite 710
Washington, DC 20036
202-296-3920 (tel)
202-296-3948 (fax)
www.cnfa.org

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Lists of Acronyms

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

Acknowledgments

There had been a number of previous reports that were useful in providing valuable data, in particular *The Pre Feasibility and Feasibility reports of the Establishment of a Cold Chain System under National Trade Corridor Improvement Program* for PHDEC.

The help that Salman Khan and Shafqat Sayed provided is acknowledged. Either one or both 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, ASF Agribusiness Specialist, who provided a very useful sounding board for various ideas and concepts and the professional way in which he assisted with these sessions.

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:

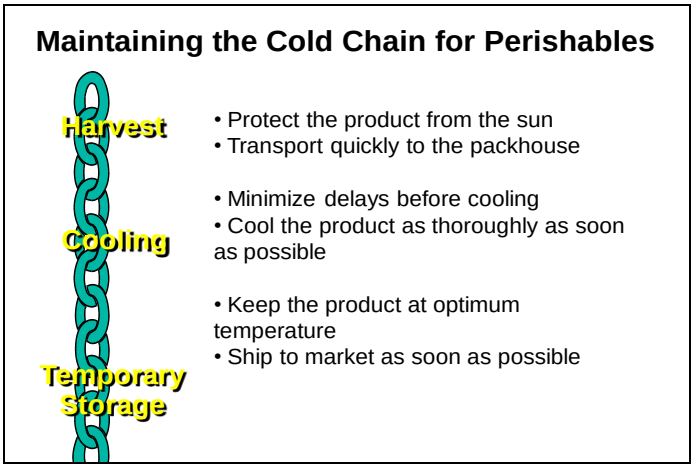
1) The need to provide clearly demonstrable benefits on the small scale
2) The reduction in the energy input into the Cold Chain
3) Improving the local infrastructure for exports and supply to the supermarket sector,
4) Training in all sectors of the value chain.

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.

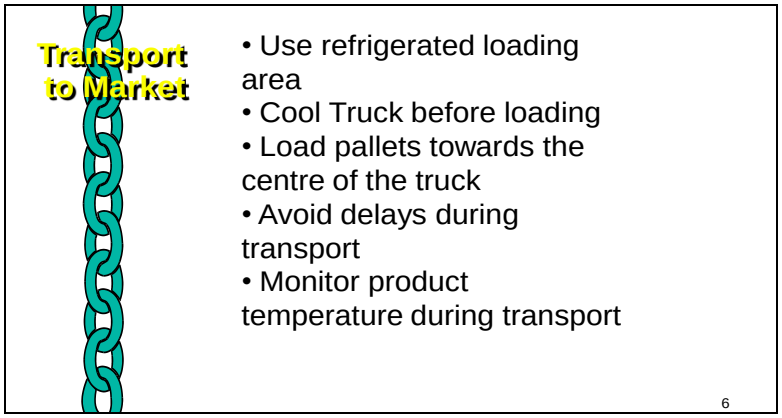
The timings of the interventions should be divided into four types; short term or in the next 1-4 months, midterm or within the next 8 months and longer term or within the next year and there will also be cross cutting interventions which will need to start within the next month but will continue through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

Cold Chain Introduction

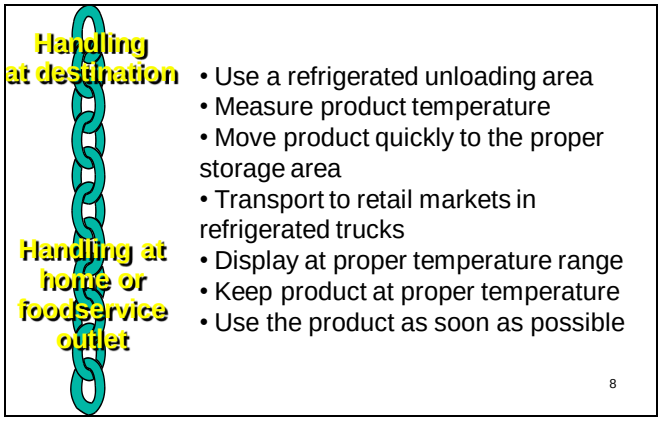
Although the expression, cold chain, is frequently used it is seldom fully understood. The parts involved are summarised in the three figures below which have been broken only for clarity but must be considered together.



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

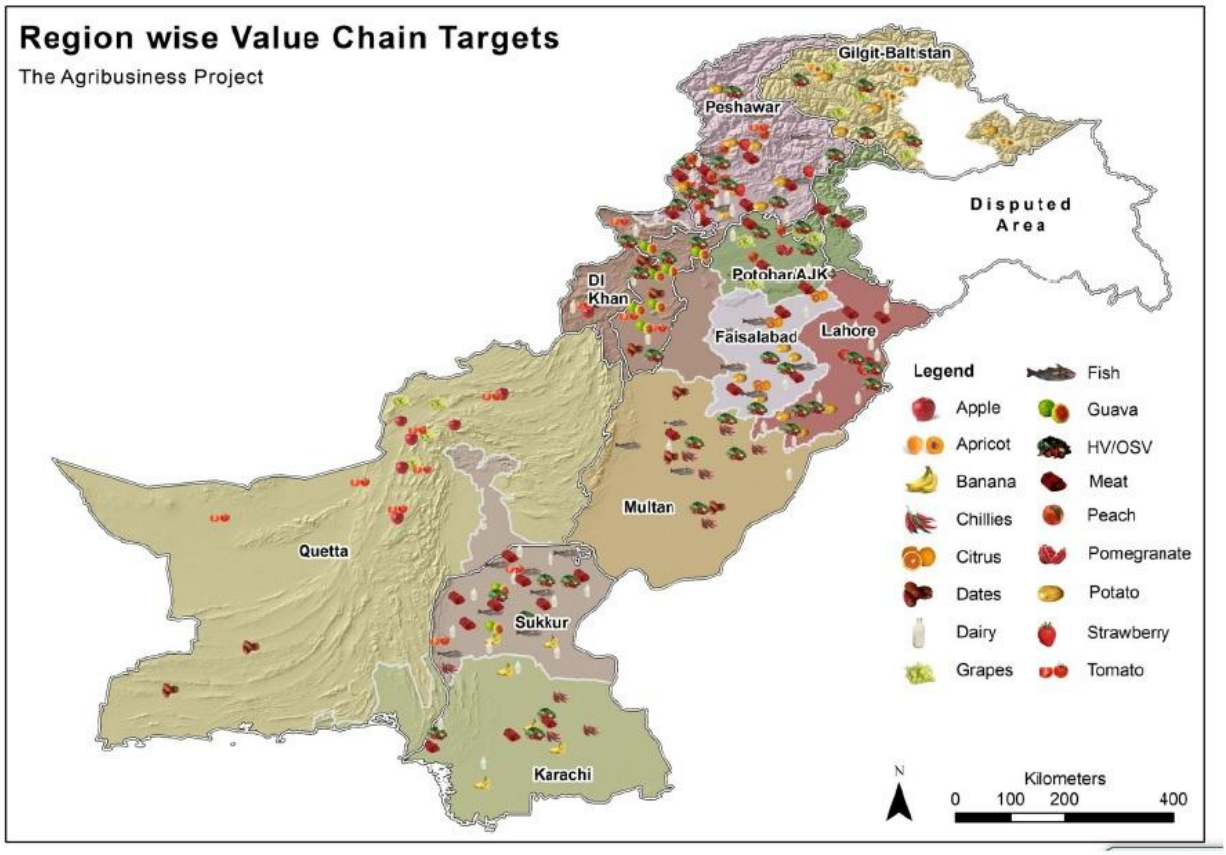
The global market for fruit and vegetables is continuing to grow with an increasing world trade. The location of Pakistan close to the growing markets of the Gulf, combined with relatively low production costs puts the country in a strong position. However, other countries, such as Egypt, have a strong 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).
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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 28^{o}C and 40% relative humidity (RH) passes through a wetted medium, in reality it should certainly be possible to reach conditions of 17.5^{o}C 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 40^{o}C 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 postharvest 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

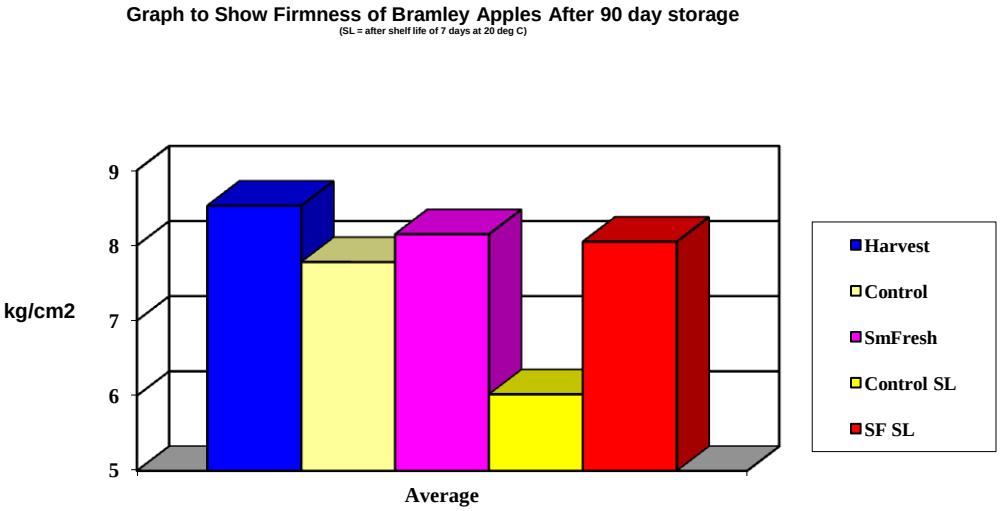
High value /off season vegetables Carrot Broccoli Capsicum	 0 (32) 0 (32) 7-10 (45-50)	 VL VL L	 H H L	 M M L	 6 months 10-14d 2-3 weeks	
Meat or fish frozen	-18 or lower				Long periods	
Meat chilled	-1.5 to 0 (29 to 32)				30 days, 70 days packaged	No ventilation
Veg. frozen	-18 or lower				Long periods	

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 20^{o}C compared to a small reduction with the treated fruit.

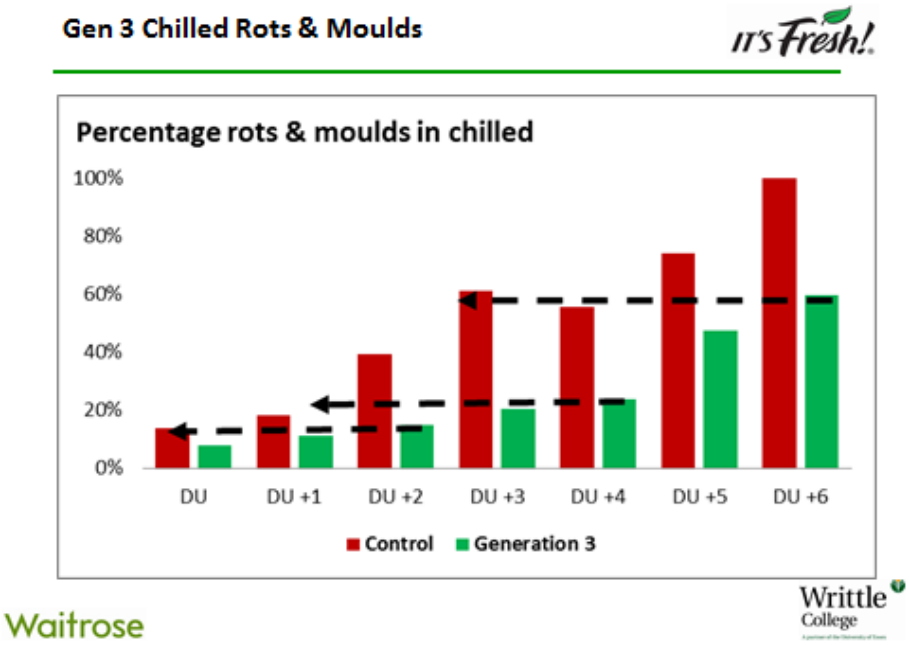


There will be issues with registration for the use of this chemical which has been passed for use in many countries such as USA, Australia, New Zealand, EU, India and South Africa. There will not be difficulties with carrying out trials. The product works on almost every variety of apples but there are 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 5^{o}C or less)
- Refrigerant not specified
- Additional fan to provide forced cooling of 0.5m^{3}/s against a water gauge of 10mm.
- Single phase operation
- Single phase generator to provide power for the above if required

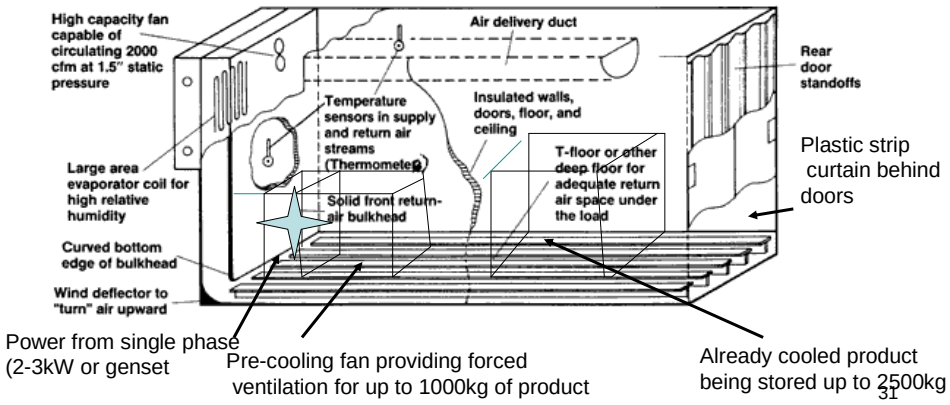
Calculation and assumptions (all assumptions are starred *)

	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



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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:

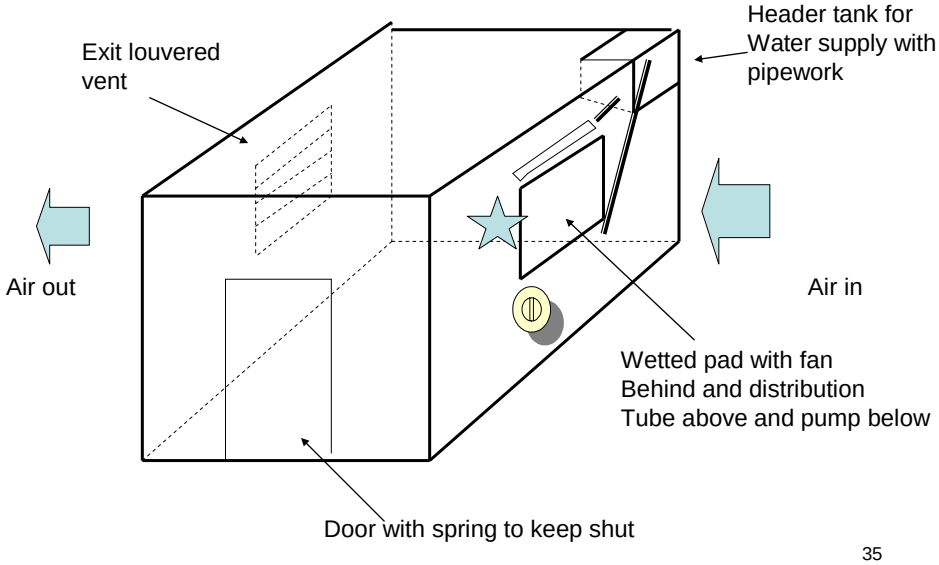
- Fan: 0.6 m^3/s against 5 mm water gauge (probably 720 rpm)
- Pump: Capable of delivering 1 litre per minute against a head of 2.5m. The pump should be in a small sump tank of approximately 20 litres.
- Wetted pad: Area 0.9 x 1.2m with wood wool 50 mm thick or equivalent (probably held by chicken wire). (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

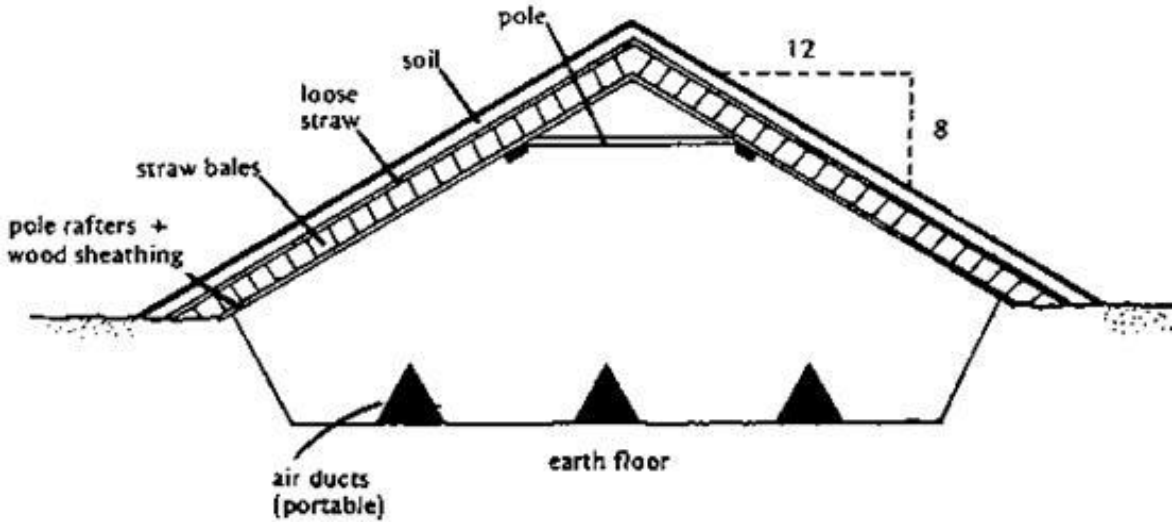
Wall area					793.7254	sq metres
If store at	5	deg C				
ambient	60	deg C	(solar heat gain)			
ambient	35		shaded			
Heat flow with traditional insulation 5 years old					25211.38	W
Heat flow with panels		(shaded)			5920.152	W
This is	difference				19291.22	W
Assuming a COP		2.5			7.716489	kW
At	15	Rs/unit			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 5^{o}C or less)
- Refrigerant not specified
- Additional fan to provide forced cooling of 1.0m^3/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 13.5^{o}C
- Day 2 Ethylene applied from generator and temperature allowed to rise to 17^{o}C
- Day 3 Ethylene generator switched off and product inspected, temperature maintained at 17^{o}C
- Day 4 product inspected, temperature maintained at 17^{o}C
- Day 5 product inspected and probably removed for market, if not maintained at 17^{o}C

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.

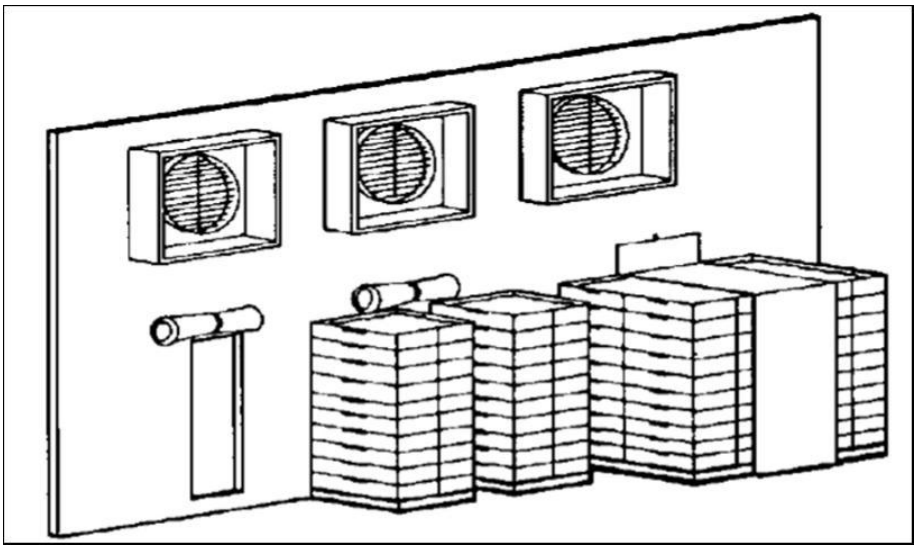
Specifications:

- 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 5^{o}C or less)
- Refrigerant not specified
- Additional fan to provide forced cooling of 1.5m^{3}/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