Extending the Apple Season: Cold Storage in Himachal Pradesh, India

Abstract

In Himachal Pradesh, India, farmers are forced to sell immediately after harvest or lose their crop to disease and rot. This project attempted to understand problems affecting fruit and vegetable farmers and identify ways to alleviate them. To this end, we interviewed farmers, storage facilities, and a local non-profit organization, and conducted research into modern farming practices. Our work resulted in multiple recommendations for improving farmers’ livelihoods in addition to the development of an app and pamphlet for their benefit.

Team Members:
Mohit Jain, IIT
Nimit Kalal, IIT
Virginia Massa, WPI
Peter Melendez, WPI
James Muller, WPI
Kunal Shah, WPI

Advisors:
Dr. Jaspreet Kaur, IIT
Dr. Rik Rani, IIT
Professor Fabio Carrera, WPI
Professor Svetlana Nikitina, WPI
Helping Farmers Preserve Crops in Himachal Pradesh

Agriculture is a very significant part of the economy in Himachal Pradesh, yet farmers have few means to preserve their crops. According to a 2012-2013 report submitted by the Economics and Statistics Department of Himachal Pradesh, about 69% of workers in the region are employed in agriculture. In addition, 87% of farmers are small-scale (Choudhary, 2016) and own, on average, two acres of land (Singh et al., 1997). With few options in terms of long term storage or preservation of crops, farmers often use relatively ineffective home-constructed storage methods (Overview of grain drying, 2017). As a result, farmers often need to push most of their goods to market immediately, driving prices down and leading to lower profits (Sidhu, 2005, and Bhandari, 2016). Figure 1 demonstrates this vicious cycle.

Our mission was to design and evaluate a solution empowering farmers in Himachal Pradesh to better preserve their crops and extend their seasons, improving their profit potential. In our research, we analyzed ways we could either help farmers avoid crop damage, or increase shelf-life. Each of these methods could potentially help farmers increase profits by either minimizing loss or maximizing the sale price.

Our first objective in achieving this goal was to investigate current food preservation practices in areas near Mandi by interviewing farmers and markets, and determine the problems farmers face. Our second objective was to research and assess alternative preservation plans that would benefit farmers. Our final objective was to select one optimal plan that would maximize farmers’ profits, and devise a way for farmers to take advantage of that plan.

Figure 1. The cycle trapping farmers in this region.

Challenges Faced by Himachal Pradesh Farmers

Himachal Pradesh is one of the northernmost states of India. In this fairly temperate region, a variety of fruits and nuts are grown (State Department of Horticulture, 2016). The weather in Himachal Pradesh is hot and dry in the summer, rainy during the monsoon season, and chilly during the winter. According to the Koppen classification system, much of Himachal Pradesh has a “cwa” climate (Grieser, Rubel, Beck, Kottek, & Rudolf, 2006). This is known as a humid subtropical climate, with relatively dry winters and warm summers (Arnfield, 2016).

The region of Himachal Pradesh borders the Himalayas and consists mostly of hills interspersed with river valleys. A case study by Singh et al. in 1997 found that both terraces and paddies dot the region, such as those in Figure 2. Pandey (2009) notes that apple orchards are especially common, with production of apples comprising 88% of fruit production.

Figure 2. Terracing style of three farms in Kataula, Himachal Pradesh.
Benefits of Cold Storage

The climate and geography of this region is conducive to large harvests. The warm weather and rain make the area very suitable for growing fruits and vegetables. The monsoon season, from July until September, brings plentiful rain to needy crops, hastening growth (Arnfield, 2016). However, these conditions are very poor for storing crops in the open or in makeshift storage. Refrigerated or controlled atmosphere (CA) storage can extend the life of crops a great deal, especially in the case of the ubiquitous apple (Refrigeration, 2015). While apples in the open may be lucky to last a week, Fischbacher and Marsden (1966) indicate that refrigerated or controlled atmosphere storage can preserve them up to six months, as shown in Figure 3. If apple farmers are able to use this technology, they can safeguard their crops from the weather and other dangers, and have a better chance to sell at market.

Lack of Storage Leads to Waste

Faced with a bumper crop, many small-scale farmers, are unable to find adequate storage before their crops can be brought to market (Bodh, 2015). As of May 2015, there are only 7 cold storage facilities in the region (Bodhi, 2015, Sharma, 2013, and Sally, 2011). Figure 4 demonstrates that Himachal Pradesh is in desperate need of cold chain infrastructure as compared to other Indian states. According to a book by Batt, P. and Cadilhon, J. (2007), Himachal Pradesh is the second largest producer of apples in India. However, the lack of infrastructure and failure to properly handle goods leads inefficiency and crop loss. Apples often become bruised or punctured during harvest, making them rot faster. Even short-term storage arrangements such as trenches and small cellars are vulnerable to attacks by monkeys and other destructive animals or insects. This type of storage also does little to prevent normal spoilage, as it is at nearly ambient temperature. Single trucks are packed to the brim for a two-day journey, leading to further bruising, deformation, and other types of damage. A single farmer might lose more than half the crop before it even has a chance to sell. Even after arrival at market, apples are often improperly stored before they are sold.
The myriad of problems plaguing apple farmers is similar to problems for many other crops in Himachal Pradesh; high-temperature storage and lack of care during transport leads to crop decay and loss. The skin and peel of fruit provide a physical barrier keeping bacteria out of the inside flesh. If their stems are randomly placed, however, peels could be punctured in transit. The fresh opening in the fruit will rot more quickly (Harvesting and Food Handling). Furthermore, the fruit becomes a food safety issue, as consuming fruit which has been punctured and exposed can cause illness (Parasites, 2013).

Methodology

This project was geared toward discovering problems with crop preservation faced by farmers in Himachal Pradesh and ways to alleviate them. The end result is meant as one improvement on their situation, alongside several recommendations for further work. An overview of our project’s strategies can be seen in Figure 5.

Objective 1: Investigating current practices

We began by conducting interviews with small-scale fruit and vegetable farmers near the IIT Mandi campus in order to understand what types of problems they face in the post-harvest handling or preservation of their crops. We interviewed vegetable farmers in Kataula, pomegranate farmers in Bajaura, mango farmers in Budhar, and apple farmers in Patlikuhal, see a map of locations in Figure 6. We also conducted an interview with the president of the Kullu Fruit Growers’ Association in Patlikuhal to gain insight on problems faced by the apple farmers residing in this region. Interviews were conducted in Hindi, and simultaneously translated to English on
In addition, we interviewed owners of market stalls in Mandi to determine crop prices both in and off season. These interviews were meant to build our perspective on the economic situation of farmers in the area and the problems they faced in terms of crop loss.

Furthermore, we traveled to Patlikuhal, north of Kullu to conduct research on whether or not apple farmers in the area could benefit from nearby cold-storage opportunities. While there, we talked with owners of Aromatrix Flora Private Limited, a small private cold-storage facility, and HPMC Patlikuhal, a large government funded cold-storage facility. We obtained a broad overview of their operation, how fruit or vegetable farmers in the region might benefit from cold-storage, and the cost to rent these facilities. Our research helped us determine exactly how we could assist farmers in this region and what methods would be best to recommend.

Results and Discussion

The interviews we conducted with fruit farmers helped us identify causes of crop loss and current methods farmers use to extend shelf life. We researched globally used preservation methods, and discussed cold storage at two facilities in Patlikuhal. Information gathered from visiting markets in Mandi allowed us to analyze the costs and benefits of these methods and select an optimal plan.

Preservation Methods Currently Used by Farmers

Both apples and mangoes suffered losses from bruising and rot, while all fruit farmers needed to contend with diseases (see Table 1). In order to avoid further loss, every farmer attempted to sell their crops as quickly as possible.
In every case, however, these fruits were left outside, under a tarp, or in crates for nearly a day. Most took precautions such as destroying or burying fruit that is bruised, rotting, or diseased before loading it for transport. Every farmer shipped in wooden cartons or plastic crates, but relatively few took further packing measures such as using newspaper to line individual fruit or wrap crates. Some mango farmers used pesticides to help control infestations of their crops, but no other farmers used chemical treatment of any sort, some believing it degrades quality.

**Established Methods to Increase Shelf Life**

Once we understood the problems faced by farmers, we researched methods scientifically proven to extend shelf life. We considered four main types of techniques: chemical treatment methods, water treatment, improved packaging, and refrigeration.

**Chemical treatments** sprayed or coated on fruit some time before harvest can preserve them for up to another two weeks. Most treatments either slow ripening or kill bacteria and harmful insects. While effective in helping fruit reach market, these treatments are costly without adding any value to fruit, making them cost-prohibitive for farmers.

**Soaking** freshly picked fruit, especially the vulnerable mango, in hot water (near 100°C) for about one hour will kill bacteria and infestations, and discourage other pests from attacking them. This method can help mangoes remain fresh for two to five days longer. However, this treatment requires a great deal of energy, rendering it too costly for farmers.

**Packaging improvements** can reduce losses and preserve them for another few days. Inexpensive improvements such as the use of corrugated fiberboard boxes, as well as cushioning fruit with material such as dry grass or old newspaper, will ensure more fruit survives to be brought to market. These methods are both effective and within farmers’ means for crops sold immediately to market.

**Refrigeration** is a way to greatly extend the life of certain crops, and to increase the profits of farmers through selling off-season.

Our interviews with produce vendors in Mandi markets indicated major price fluctuations during the year (see Figure 7). If stored for several months, fruit might be sold for anywhere from 2-5 times the original price.

<table>
<thead>
<tr>
<th>Crop</th>
<th># of Interviews</th>
<th>Reported Loss before Sale</th>
<th>Primary Cited Reasons</th>
<th>Average Wait</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>3</td>
<td>15-20%</td>
<td>Bruising, rot, disease</td>
<td>1 day</td>
</tr>
<tr>
<td>Mango</td>
<td>3</td>
<td>25%</td>
<td>Bruising, rot, disease, infes-</td>
<td>1-2 days</td>
</tr>
<tr>
<td>Pomegran-</td>
<td>6</td>
<td>5-10%</td>
<td>Disease</td>
<td>&lt;1 day</td>
</tr>
<tr>
<td>Vegetables</td>
<td>2</td>
<td>10%</td>
<td>Rot (unseasonal rain)</td>
<td>12 hours</td>
</tr>
</tbody>
</table>

Table 1. Loss percentages, cited reasons, and time before sale for several types of crops.
Extending shelf-life with Cold Storage and Controlled Atmosphere

Our research into refrigeration indicated that of all fruits and vegetables, the storage life of apples is extended six months, well into the off-season where they can be sold for more (see Table 2). Other fruits and vegetables, however, do not benefit significantly enough to be sold off-season (see Figure 7). However, none of the apple farmers we interviewed north of Kullu actually stored their crops in the two controlled atmosphere facilities available nearby. When we interviewed staff at those storage facilities, both indicated that they would like to rent space, but currently cannot find interested farmers, despite low costs. Our interview with the Kullu Fruit Growers’ Association revealed that farmers have difficulty organizing to rent a large chamber; furthermore, storing the minimum 150 days that such controlled atmosphere facilities require poses a financial difficulty for them.

Cold Storage vs. Controlled Atmosphere

The controlled atmosphere facilities indicated that their space could be rented for just under 1 rupee per kilogram per month, but would need at least 200 metric tons in order to fill a chamber. Alternatively, these facilities could purchase apples from individual farmers at 3-4 rupees more per kilogram than market price, and sell the apples themselves off-season; when purchasing in this fashion, they will buy a minimum of 50 kg from each farmer. Both these options pose a potential profit for farmers, provided they can bring enough good quality apples that the facility will accept (see Figure 8).

Discussion: Lack of Communication and Awareness

Although it is the government’s policy to help farmers by spurring the construction of cold storage through subsidies, there appears to be a disconnect between storage and farmers. The government prefers to construct large controlled atmosphere storage facilities, which are difficult for farmers to make use of. This policy may indicate failure to understand farmers’ needs and means in the region. Furthermore, there is a lack of awareness on the part of the farmer both about the benefits of cold storage and about the existence of such facilities nearby.

Opportunities for farmers to learn are sparse. The Kullu Fruit Growers’ Association indicated they conducted training events and workshops.
No one we interviewed knew of any government-run workshops, indicating that they may be insufficiently marketed. If farmers had more opportunity to connect and learn, they could improve their techniques, make use of storage, turn greater profits both in and out of season, eventually break the cycle currently trapping them, and improve their economic situation.

Multiple limitations on our work made it more difficult to draw relevant conclusions. The major limitation has been the language barrier, as farmers and officials alike spoke little English. This barrier has made it difficult to ask exactly the questions we wanted, and may have skewed the information we obtained; for instance, we needed to call back the controlled atmosphere facilities multiple times for clarification.

Moreover, because we gathered data exclusively through interviews, we needed to account for personal bias. Farmers may not have been inclined to be entirely honest with us, fudging numbers to inflate production or downplay losses. In addition, our small sample size, due to time constraints and difficulty in finding farmers willing to interview with us, means our data does not necessarily capture average farm size and amount produced.

**Conclusions**

Cold storage is gradually expanding within Himachal Pradesh, but farmers still are struggling to use the resources at their disposal. Since many farmers are small-scale in nature, our research indicates that they are struggling to profit not only because they have few ways to ensure crops reach market in good condition, but also because they cannot afford to use things such as cold storage to their advantage. Several farmers indicated that they were aware that cold storage existed, but that they believed it was of little benefit to them. Moreover, farmers have very few means of communication with each other and potential buyers, including cold storage facilities. In order to rectify the situation, and increase the standard of living for farmers across the Himalayan foothills, better communication channels should be established.

Our many interviews indicate that farmers would greatly benefit from outreach in addition to current training programs, improving their access to useful knowledge about both caring for crops and storing them until they can be sold for higher profit. Unfortunately, a major obstacle to farmers is their relative lack of funds. The proper way to remedy the situation is to move slowly, step by step, and give farmers the tools they need to improve their livelihoods over time. If farmers were to find a way to organize and act as a group (e.g. a coop), they would be able to have greater influence over market prices and better ability to store and sell their crops when it is most beneficial to them. With greater communication and more opportunities to work together, the formation of such farming cooperatives may come to pass. In time, farmers may claim a better place in the economy of Himachal Pradesh.

**Project Outcomes**

In order to help farmers coordinate and increase awareness of both good practices and cold storage, we have created **two major deliverables**. The first of these is a pamphlet geared at apple farmers describing good practices for handling and packaging the fragile fruit. The pamphlet also contains details of cold storage and its benefits, notably the ability for greater profit from each harvest. The pamphlet can be distributed by the Kullu Fruit Growers’ Association or the government in addition to their normal workshops, as a guide to farmers.
The second deliverable is a dual purpose **mobile Android application**, also geared toward apple farmers. Part of this app will be educational, informing farmers of good agricultural practices and how to handle and care for the apple fruit. The app also will contain information on cold storage and its benefits, and how farmers can work together to rent even large cold or controlled atmosphere storage spaces collectively. The other major part will **allow farmers to find cold storage facilities nearby** and share their interest in storing there to other farmers. In this way, multiple farmers who are interested can collaborate and rent a single unit which none of them would have been able to fill individually. Through this app, cold storage facilities would be able to send updates and announcements to farmers, and help organize space rental. See Table 3 for an outline of all our project goals and how our deliverables and recommendations tackle them.

**Recommendation for Expanding and Improving Cold Storage**

We would like to encourage the government of Himachal Pradesh and private companies to attempt to set up relatively small cold storage facilities. Costs to maintain such smaller facilities will be higher than current, so work will need to be done in the local community to ensure farmers are aware of them and they are used extensively. The primary use of this cold storage will be to allow farmers to reap the benefits of off-season prices. The extra storage space will be another step in bringing fresh fruit to Himachal Pradesh year-round. As a further step, when funds become available, refrigerated trucks ought to be gradually phased in to maintain fruit quality. Moreover, new and existing storage can look into compartmentalization for greater access to smaller farmers, and ensure they have a sign out front advertising their presence.

**Recommendations to Decrease Crop Loss**

There are a few cheap methods available to help apple and mango farmers deliver their harvest to market unharmed. Both fruits are easily bruised, even though apples may seem firm; care should be taken during harvest and storage not to drop or bounce them around. **Corrugated fiberboard boxes stuffed with dry grass or hay** is an effective way to package and transport crops. These materials give a boost to survivability in transport, and have a negligible cost.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Increase farmer</th>
<th>Increase Communication</th>
<th>Increase Accessibility for small</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deliverables</td>
<td>- Android Application</td>
<td>- Android Application</td>
<td>- Android Application</td>
</tr>
<tr>
<td>Recommendations for the future</td>
<td>- Sign at cold storage</td>
<td>- Push SMS notifications</td>
<td>- Farming cooperatives</td>
</tr>
<tr>
<td></td>
<td>- Workshops</td>
<td></td>
<td>- Expanding cold storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Smaller facilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Compartmentalization</td>
</tr>
</tbody>
</table>

Table 3. Overview of project outcomes.
**Future Project Recommendations**

Further projects might be undertaken at IIT in order to continue our work. Our app needs further development and community participation to truly become a useful tool for farmers and storage alike. Cold storage and farmers should be able to register and find each other. Farmers should also be able to communicate and work together to bring goods to market at better times or store them together to reduce costs. Some obstacles to be overcome include understanding farmers’ needs thoroughly and spreading the word to many different villages. As another possibility, a push SMS plan for farmers without smartphones could work to help them coordinate to meet needs. We are aware of at least one established network, mKisan, which offers such notifications to farmers.

A second possible project would be looking into the possibility of forming farming cooperatives in this region. Farmers usually work within their families and have wildly varying practices and associates. As a cooperative, farmers have an easier time storing crops, can support each other, and can work together to improve their livelihoods. Overall, the formation of cooperatives would be a major next step for farmers in Himachal Pradesh both financially and socially. Some major problems that need to be overcome are linking enough farmers, generating interest, and distrust and disagreements between farmers. While apple farmers may benefit the most from cooperatives in this way, any group of farmers can work together and improve their conditions.

**Acknowledgement:**

We would to thank our advisors, Professors Jaspreet Kaur, Rik Rani, Fabio Carrera, and Svetlana Nikitina for all of their support and feedback, especially with all the twists and turns this project has taken. We would also like to Devika Sethi for all of her help and information and our TA, Vipul Sharma, for the assistance with finding and getting in contact with farmers.
References


• mKisan [http://mkisan.gov.in/](http://mkisan.gov.in/)

• Research and development issues in grain postharvest problems in Asia - Overview of grain drying and storage problems in India (cont.). Retrieved February 05, 2017, from http://www.fao.org/wairdocs/x5002e/X5002e02.htm#Storage%20of%20food%20grains


