Chapter 05

HOW CAN YOU START USING COLDTIVATE?

Coldtivate is a **free-to-use, data science-based mobile application** that caters to cooling companies, operators, and users, enabling them to transition from manual registers to efficiently managing rooms and monitoring the quality of stored crops on their phones.

YOUR VIRTUAL COLD
CHAIN ASSISTANT

5.1 HOW CAN YOU JOIN COLDTIVATE?

Cooling companies, cold room operators, FPOs, farmers and traders can register for free on Coldtivate.

Cooling companies: The first registered employee (RE) of the cooling company, typically from the management team, that signs up to Coldtivate should '**Sign up as company**', where both the company and the user are registered. Once registered, the RE can sign in and invite other REs and operators to join the company. All registered employees have the same permissions within the app, regardless of whether they were the initial RE or invited later. To invite other registered employees, go to the **Management → Registered Employees** section. Click on the '**+**' sign to send a registration link via SMS to their phone numbers.

Operators: In the context of the Your VCCA project, **we define operators as the persons physically present at the cold room premises, who manage the interactions with the cooling users, perform check-in and check-out operations at the rooms, and collect storage fees.**

Depending on the project configuration, operators could be employees of the cooling company, members of a farmer producer organisation, a farmers' cooperative society, a self-help group, or an independent farmer or trader hired from the local community to run the rooms (see **Chapter 3, Section 3.1.3** for more information).

For simplicity, in Coldtivate, this user type is assumed to be linked to the company maintaining the cold room and thus needs to be invited by a registered employee to join the company in the app. Operators can sign up following an invitation URL sent by SMS with a phone number (no email needed).

Cooling users: Smallholder farmers and small-scale traders can sign up on Coldtivate independently of any cooling company, if they have access to a smartphone. In the welcome screen, they can click on '**Sign up as a cooling user**' and provide their phone number and other personal information to register. This allows them to log in and locate cold rooms in their vicinity to start benefiting from cold storage. Farmers and traders without access to a smartphone can be registered in the app by the operator of the first room where their crates are being checked in, using their phone number as identifier. For users without a phone number, the operator can record check-ins and check-out for a generic user, named '**User without a phone**'.

5.2 WHAT ARE THE MAIN FUNCTIONALITIES OF COLDTIVATE?

Coldtivate enables cooling companies to digitally manage the inventory of each of their cold rooms and remotely monitor room occupancy, finances, and temperature. Simultaneously, the app empowers farmers to track the remaining quality of their stored produce, monitor cold room conditions, and access information on post-harvest best practices.

i) The primary responsibilities of registered employees include setting up the cooling units on the app, inviting other REs and operators to join, and assigning operators to specific cold rooms. To add cooling units, navigate to the **Management → Cooling Unit** section. Additionally, REs must add the geographical location of each room under **Management → Location.** This step is crucial for distinguishing between multiple units situated in the same market. If temperature sensors are present in the cold rooms, they can be linked to Coldtivate as a cooling unit property (as shown in the image).

ii) All registered employees of the company can manage the assignment of operators to cold rooms. To invite operators to join a cooling company, navigate to the **Management → Operators** section in the menu and click the **'+'** sign. An automatic invitation link will be sent via SMS to their respective phone numbers.

Operators can be assigned to cold rooms during the invitation process by editing the **Operators** field on the **Cooling Unit page.** Alternatively, assignments can be made by editing the **Cooling Unit list** on the **Operators page.** It is important to note that operators can only monitor and perform check-ins and check-outs in rooms to which they have been specifically assigned.
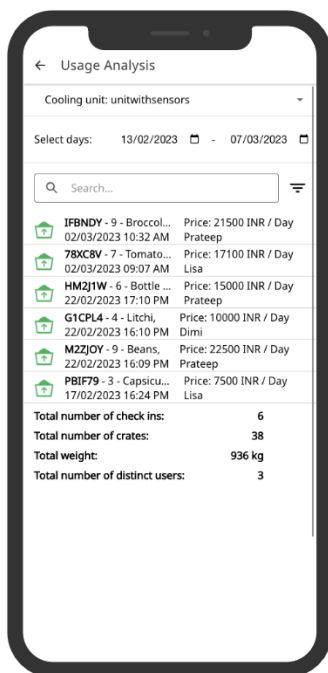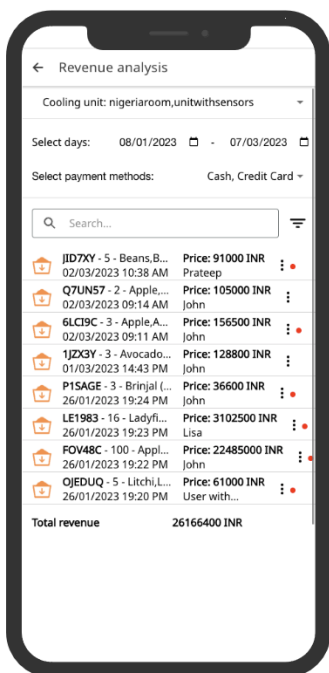
iii) The **Revenue Analysis** option under the **Management** menu allows REs and operators to assess the total revenue generated during a specific time frame for one or multiple cooling rooms. On the other hand, the **Usage Analysis** feature provides an overview of the number of check-ins, users, and crates for one or multiple cooling rooms within a given period.
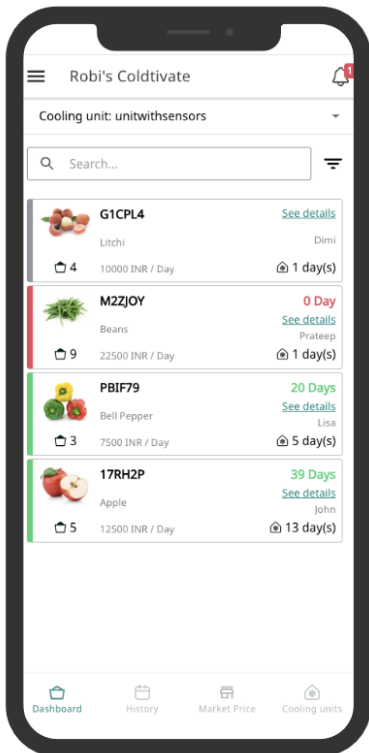
iv) The crates currently in storage in a cooling unit can be seen by selecting a cooling unit from the dropdown in the **Dashboard** menu. Each crate's information includes the user's name, crop type, pricing scheme, days in storage, and the remaining days until the specified time-to-pick-up (TTPU), indicated by a colour code. Green indicates more than 5 days remaining for TTPU, yellow signifies TTPU within the next 2-5 days, and red suggests TTPU within the next 2 days. The colour can be grey for crops without a digital twin (DT) or if the DT model is deactivated for the company. Clicking on each card provides additional details about the stored crates and the cooling user's contact information, if necessary. The page also offers a search and sort option to quickly find specific crates of interest. Each cooling user can only visualise their own crates in storage in the **Dashboard,** whereas the operators and RE have full visibility on all crates currently stored by different users in a given day.
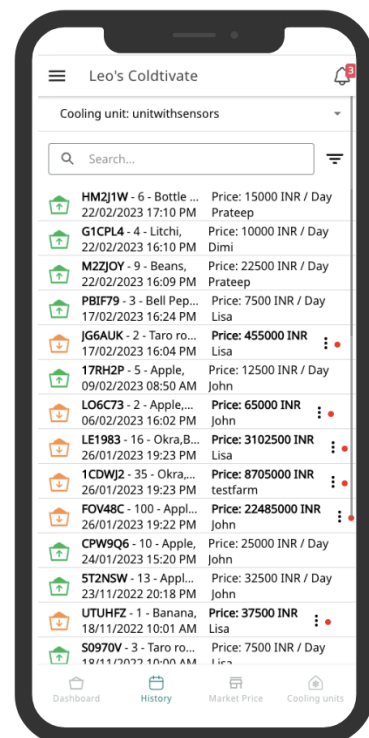
v) All users can use the **History** tab to select a cooling unit, track all past crate movements (check-ins and check-outs), and download receipts for crates that have been withdrawn. Check-ins will be displayed in green (representing arrivals), while check-outs will be showcased in orange (indicating departures). Additionally, you can effortlessly monitor the corresponding fees owed, ensuring a comprehensive overview of the financial aspect tied to each crate. As for the **Dashboard**, cooling users only see movements they have undertaken, while operators and REs can view all operations performed in a given room.
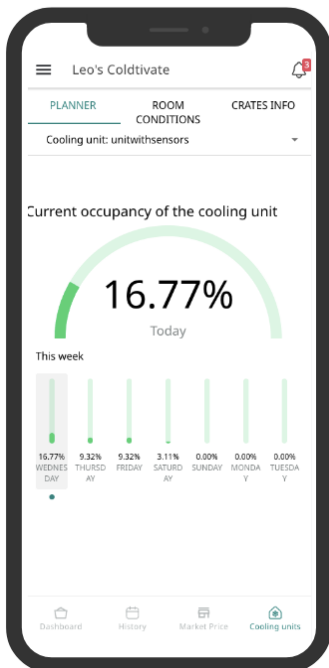
vi) Under the **Cooling Units** section, users can visualise the current and predicted occupancy for each room they are linked to (in the **Planner** tab), the room temperature in the last 7 days (in the **Room conditions** tab), and summary statistics of all crates in storage organised per crop type and weight (in the **Crates info** tab; this is only available to RE and operators). In the **Maps** tab, cooling users can explore cold rooms in their vicinity.
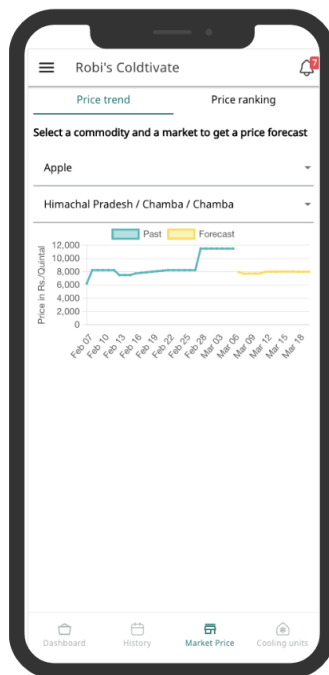
vii) By navigating to the **Market Price** tab, users can visualise historical and forecasted market prices for different commodities. The historical prices are extracted from country-specific open-source data, whereas the forecasts are the output of a machine learning model that is regularly updated to reflect the latest market trends. This feature is only available in select countries.

5.3 COLDTIVATE'S STORAGE LIFE MODEL

Fruit and vegetables are living products. Even after harvest, they keep on 'breathing' or respiring. As a result, the quality of the product decreases, changing from a fresh crop at harvest to an overripe crop during post-harvest storage.

The past decades, many supply chain stakeholders have measured how different crops behave or deteriorate at different storage temperatures. Using this data, mathematical models, called 'Shelf life models' have been established to predict the quality of the crop over time when displayed on a shelf, e.g. a shelf in the supermarket or local market, based on the temperature.

Shelf life models are a key component of the Coldtivate app: by providing regularly updated information about the remaining storage life of each crate stored in the cold room, they help cooling users to understand for how long their produce is still good for, and thus drive their decisions on the best selling time. The storability of fruits and vegetables is affected by temperature conditions during cold storage. Due to the thermal sensitive nature of fresh food, they decay gradually during long storage to a certain quality threshold, below which the product is not acceptable anymore to the consumer. Most of the temperature-induced underlying biochemical reactions responsible for quality changes of fruits and vegetables can be adequately modelled using a kinetic rate model.

A kinetic rate model is a simple mathematical expression that predicts the reduction in the quality attribute of a product per unit time. Hence, based on the temperature history, the remaining quality of each product can be calculated during storage taking into account the crop type and initial quality of the crop at check-in.

The term 'storage life' refers to the duration a product can be stored before it reaches the quality threshold for consumption. Since this prediction involves the future, Coldtivate's kinetic models for storage life calculations use the expected temperature inside the cold room, which is the room's set temperature, rather than sensor data.

On the other hand, 'shelf life' is similar to 'storage life' but pertains to a product's storability after storage when it is displayed on a shelf or market under uncontrolled ambient conditions. The temperature used in the 'shelf life' model is higher and matches the environmental temperature.

In Coldtivate, the projected check-out date for each crate displays the **'time-to-pick-up' (TTPU)**, which estimates storage life while maintaining a minimum shelf life of 0.5 days at an environmental temperature of 30 °C. This ensures that sufficient time is available to transport the products to the market and sell them after they are taken out of storage.

When calculating the TTPU, the following considerations are taken into account:

i) Fruit and vegetables are living products which are subjected to biological variability. Due to this biological variability, every product will respond differently. For example, every product has its own size and shape, but even when you take 2 products which look similar and are harvested at the same farm, they can still show different storage lifes. The digital twin model is a virtual representation to calculate and predict how the real crop is behaving 'on average'.

So, the general message here is that you have to interpret the TTPU with care. When the TTPU is indicated as 5 days in the app, it could be that some products in the crates will have a TTPU of 4 or 6 days. The goal of the digital twin is to give an estimated value for the expected storability (where the order of magnitude is important, for example, 1 day versus 5 days versus 2 weeks) to be able to keep track of the quality of different crops inside the room and minimise losses. When multiple crops are stored, the digital twin helps to indicate which products should be taken out soon (TTPU of around 1 day), or which can be stored for a longer time still (TTPU of multiple days or even weeks).

ii) The initial quality of the produce when it is brought to the room plays an important role in determining the TTPU accurately. For example, if a crop had to travel unrefrigerated for 4 days before reaching the cold storage room, the quality when arriving at the room will be drastically lower than the freshly harvested crop, leading to a decreased storability (lower TTPU). When a crop is checked-in into Coldtivate, the operator is prompted to ask the cooling user about when the crop was harvested (today, yesterday, 2 or more days ago). These answers map to a crop-specific quality value which is calculated assuming the crates have been stored unrefrigerated between harvest and check-in, and that is used as the initial TTPU. To be able to predict the quality at check-in as accurately as possible, it is important to answer this question honestly.

Within the calculation, it is assumed that the crop was kept at a constant temperature of 30 °C when travelling from the farm to the room. Probably, the temperature was variable throughout the day (e.g. lower during the night), which would influence the quality at check-in (e.g. the quality decreased less compared to storing continuously at 30 °C). If the crop was harvested, for example, 1.5 days ago, it would be appropriate to indicate '1 day ago' in the question at check-in in the app. In future versions of the app, the calculation can be refined to account for day and night temperatures based on the geo-location of the farm and cold storage room.

iii) The digital twin uses temperature sensor data to calculate the remaining quality during storage. To incorporate temperature variations in the room (e.g. room temperatures higher than the optimal temperature of the product, temperature peaks during door openings, etc) the model regularly recomputes the remaining quality of each crate.

To improve the model accuracy, it is important that the sensors are properly installed inside the room, so that the temperature measurements are representing the temperature the crops are experiencing. Hence it is crucial to make sure that the sensors are not accidentally taken out of the room, and that the sensors are functioning properly at all times and are able to send data to the cloud storage.

iv) The TTPU can be seen as a prediction in the future about 'how long can the product still be stored inside the cold storage room'. As we do not know what the room temperature in the future will be, we use the set temperature within the room to calculate the TTPU, assuming that in the upcoming days, the temperature within the room will equal the set temperature. Coldtivate is being refined to calculate the set temperature as follows:

a) If the room is equipped with sensors connected to the Coldtivate app, the default setting is that the average temperature of the past 6 hours is taken as the set temperature.

b) If the room sensors contain the set temperature as part of the API response, that value is used as a set temperature in the TTPU model.

c) If no sensor data is available for the room, Coldtivate uses the last manual temperature as the set temperature.

The rate of quality loss and hence the storability are highly dependent on temperature. When the temperature increases, the expected storability also decreases. To make sure the displayed TTPU is as accurate as possible, the model is recomputed multiple times per day using the latest available temperature traces.

v) The digital twin currently assumes that the crops are harvested fully ripe. However, some crops, such as banana and tomato, might be harvested unripe (in a green stage). The ripening model is currently not yet implemented in Coldtivate. As a result, when green bananas or green tomatoes are brought to the room, the TTPU prediction will be less accurate (i.e. the TTPU will be too low).