Agfrost Crop Preservation Cooling System & ABB Robotics Project

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This document covers the content of the research completed and product designed for The Global Innovation Program at La Trobe University in Melbourne, Australia in the summer of 2023. The research conducted was based on agricultural practices in Bosnia and Herzegovina. Storage processing proved to be a large problem area for small farmers. A solution model was created for this problem area with budget, materials, and technology access in consideration. This project is a collaboration with students from La Trobe University. The document also describes the operation method and programming details of a project for the ABB robot instructed by the Deutsches Kompetenzzentrum Für Robotik (DKR) Training in Tuzla, Bosnia and Herzegovina in the summer of 2023.

I. Introduction

Bosnia and Herzegovina aims to integrate into the European Union. In response to their membership application in 2019, they were provided with priority reformations to work towards for consideration. To align with the EU in order to be able to implement legislation, agriculture and rural development is a focus area. The *AgFrost* storage model can help to increase yield, improve the competitiveness of their products, increase incomes, and increase employment.

II. Agriculture Processes

Bosnia and Herzegovina has more than 500,000 owned farms, it is thought that, of the nation's population, which is estimated to be about 3.8 million, 33% is engaged in some form of agriculture.[1] Bosnia Herzegovina's main outputs of farming include, wheat, corn, and potatoes. Wheat is one of the staple crops grown in Bosnia it is primarily grown in the central and northern regions of the country, contributing significantly to the economy by supporting the local milling and bakery sectors. Corn is another essential crop seen growing in BiH's agricultural landscape, cultivated across the country with a particular focus on the central and eastern regions. It is vital in the livestock industry, providing food for cattle, pigs, and poultry. Additionally, it is used in the production of biofuels and contributes to BiH's renewable energy sector. The main problem with the agricultural sector is the low productivity, both per unit of production and per farm. This is due to the small-scale farms focusing on the growth of crop to maintain the farm and livestock rather than orientated towards a commercial market.

A. Growing

Seeds are planted across fields and are curated to become mature plants. The mature plants have many forms: trees produce fruits such as apples, vines produce fruits such as grapes, and other ground-based plants produce vegetables such as potatoes and carrots. Irrigation systems, if available, help to get water to crops to ensure a steady and healthy growth. Area with limited irrigation must focus on more old school methods of watering the crops by hand. Fertilizer is applied to crops to further maintain the health and growth of the plant. BiH uses 90.1 kilograms of fertilizer per hectare of arable land, as of 2020.[2]

B. Harvesting

Each crop has varying time needed to produce mature fruits and vegetables for harvest. When ready, the fruits and vegetables are harvested in two main ways. For the more advanced farms within Bosnia and Herzegovina mechanical harvesting may be an option. This consists of using large machinery such as tractors and combine harvesters. The smaller farms must rely on harvesting by hand, such as hand-picking fruit from trees or digging up produce from the ground. The common ground between the two is that all workers must check that the produce is not bruised or cut. Once all the produce is sorted, they are then put into storage.

C. Storage

Small producers mostly produce for green markets or sell their products on farm where they have basic storage capacities. Whether it be small greenhouses or storing produce in the ground they are usually either beginners at farming or have large amounts of experience. Medium sized producers have years of farming experience but normally do not have modern storage capacities as well. They usually have some form of production knowledge but choose not to invest due to financial risk. Large scale producers such as fruit and vegetable companies have ULO storage (Ultra Low Oxygen). Their whole production is based on new technologies as they have the financial stability to invest in such technology.

D. Processing

Once harvest is completed, the produce is cleaned and sorted again. The final product depends on the scale of the farm. For smaller farms they usually keep most of their produce for self-consumption or for small stalls at green markets. This would mean they would either store the produce or take it directly to the market right after harvest. The same goes for medium scale producers, although some farmers may have enough experience to integrate into chain supermarkets, in which more advanced storage is needed. Large produce companies supply to supermarkets and the export market such as sending apples to the Russian Federation.

E. Distribution

This is the final step for majority of producers. The small and medium producers transport their products via unrefrigerated trucks and carts, whilst the large companies use refrigerated trucks that can regulate temperatures for all produce. Every type of producer eats the produce they grow except for the larger companies who have the sole purpose of producing for supermarkets.

III. Scope: Storage in Bosnia and Herzegovina

TABLE I: Shelf-Life and Storage Details for Various Food Products

Food Product	Common Storage Shelf-life	Cold Storage Shelf-life	Temperature	Humidity	Storage Notes
Potatoes	1 – 2 months 4 – 6 months in optimized temperature and mesh bags	10 – 12 months	3 – 4°C (seed potatoes) 4 – 7°C (fresh market potatoes)	95%	Must be in complete darkness. Must be cured before storage.
Tomatoes	3 – 7 days	2 – 3 months	13 – 21°C	85 – 91%	-
Onions	2 – 3 months	1 – 4 months	7 – 10°C	65 – 70%	Requires ventilation. Should be cured before storage.
Cucumbers	1 week	2 weeks	10 - 13°C	90 – 95%	-
Green Bell Pepper	5 – 7 days	1 – 2 weeks	7 – 13°C	90 – 95%	-
Cabage & Kale	3 – 4 weeks	3 weeks – 2+ months	0 – 4°C	95 – 99%	-
Lettuce	2 hours	1 – 2 weeks	1°C	95 – 99%	Cannot be stored near onions, apples, or pears.
Cherries	3 – 4 days	2 – 3 weeks	-1 – (-0.5)°C	90 – 95%	-
Apples	2 -3 weeks	8 – 12 months	0 - 4°C	90 - 95%	Should be individually wrapped
Pears	3 – 5 days	9 – 10 months	-1 – 1°C	90 – 95%	Should be individually wrapped
Berries	1 day	2 – 4 days	0 – 3°C	85 – 90%	Should be isolated and covered

[a.] Data is compiled from references [3] – [5] on pg. 5

Preserving fruits and vegetables can be difficult as they require a dedicated space of specific temperature and humidity conditions, individual to certain groups. Storage options can be broken into common (unrefrigerated) storage and cold (refrigerated storage). Traditionally, large scale cold storage is unavailable to small estates due to the cost of maintenance/manufacturing and the necessary occupied space. The conditions and shelf life of common and cold storage are of the summer season for the most-produced fruits and vegetables in Bosnia.

A. Small-Scale Farms in BiH

Bosnia and Herzegovina as a region are struggling to finance complex agricultural methods, especially small family farms. Development of the fruit and vegetable sector has been stunted by a lack of infrastructure, technology and access to updated methods. At small to medium estates, produce is sorted by hand, collected and transported by truck. Large machinery such as tractors or even forklifts, are not available. Small scale, semi-subsistence producers exploit old orchards, with a low rate of new orchards being produced. Majority of fruits are quickly converted to spirits, whilst the rest is self-consumed. The medium esates work on orchids with sizes of 3-5 hectares where

yields are erratic and are inconsistent in quality. These medium estates sell directly to green markets via a "middle man" who helps to communicate between producer and seller.[6]

B. Large-Scale Farms in BiH

The storage of produce within the country is very basic for small scale farms and updated for the larger chain type companies. Large scale farming companies and firms have better access to higher technology available for storage. Ultra Low Oxygen is a storage method that is defined as "a system that lowers the oxygen concentration in your store and increases the CO_2 concentration. (…) the maturation process slows down, enabling you to maintain the quality of your fruit for a longer period. ULO can be applied to both hard and soft fruits." These types of farms work across orchids that are from 5 to 50 hectares in size.[7] During summer, fruits are harvested and sorted by large machinery at optimal stage of ripeness. Individual ULOs are stacked on top of one another and when orders are needed at a different time than planned, great labor is involved in re-arranging them to acquire a fridge deep within the stack, which can be inefficient.

C. Homesteads

Homesteads often store produce in multiple spaces and plan their crops to limit the variety in conditions needed to store non-similar fruit and vegetables. Root cellaring is a food preservation method that is not labor-intensive and maintains food freshness. It requires humidity and temperature to be at a specific temperature, the farther out from these conditions, the smaller storage life available. Leave-in-ground storage involves covering existing crops with a thick layer of hay or straw and leaving until needed or until the ground freezes. Root clamping stores produce in an underground storage space which can be dug out by hand. Produce is stored straight in the ground or in a crate and then covering with insulation (Such as leaves, soil, woodchips, and straw which is slightly damp). [8] Other storage options include refrigeration (summer-storage), and cold framing (winter-storage).

D. Comparison Storage in Croatia and Serbia

Vegetable production is similar for the three Baltic countries (potatoes and cabbage crops are the most grown crops). In Croatia and Serbia, there are relatively few cold-storage facilities, with small capacities, for storing fresh vegetables (carrot, parsnip, onion, and potatoes). The storage warehouses available have limited control over the internal conditions which decreases storage time. It is estimated that Western Balkan Countries annual postharvest loss of fruits and vegetables is as high as 30 – 40, all due to limited storage and limited commercial knowledge.[9]

IV. Our Storage Solution: Modular Cooling System

Fig. 1. *AgFrost* Cooling Unit

AgFrost is a cost-effective modular cooling system that intends to keep produce fresh for longer for small scale farms. The products would be marketed primarily to small-to-medium agricultural producers, especially in BiH. The modular system has dimensions of 1.2 m x 1.2 m x 0.81 m and comes in two sections. This product allows for farmers to increase their crop yield, for commercial market purposes. This system can reduce wasted food from improper and inadequate drying and storage.

A. Section I

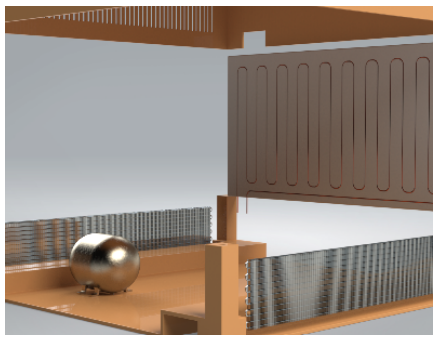

Fig. 2. Fridge Components

Section I is fitted with a humidifier to regulate humidity. It includes an integrated refrigeration unit which houses the compressor, condenser, expansion valve, and evaporator. It functions as a standard heat pump system, with focus on the temperature of the cooler temperature. Hot gas is put through a compressor which is then pushed through a condenser to turn the hot gas into a hot liquid. The highly pressurized liquid is put through a small expansion valve, cooling the liquid due to the change in pressure. This liquid is passed through an evaporator where the cool liquid evaporates, chilling the storage crate and the food product inside. This process is repeated to maintain the temperature of the unit.

B. Section II

Fig. 3. *Storage Crate*

This crate is fitted with temperature and humidity sensors to vary the environment of the crate for the type of produce inside. The storage part of the crate has a volume of 0.55 m^3 and can hold large amounts of fresh produce. For example, the crate can hold 529.2 kg of apples based on the average weight of an apple being 150 g. Airflow is minimized in this section.

C. Specifications and Features

- Ventilation Panels
- Insulation
- Stackable
- Forklift Compatible

D. Costs

TABLE II: ESTIMATED COST OF MANUFACTURE PER UNIT

	Specifications	**Total Cost**
Manufacturing Overheads	Utilities, Insurance, Repair/Maintenance, Indirect Labor Cost, Indirect Material Cost.	73 BAM
Direct Labor Cost	3 Factory Workers	4710 BAM
Direct Material Cost	8 Sheets of 300 mm x 600 mm ABS Plastic	368 BAM
	1 Refrigeration Unit	1213 BAM
	Humidifier	19 BAM
	500 mm of 3/8” Copper Pipe	11 BAM
	Total	6394 BAM (3514 USD)

[b.] The details of the manufacturing overhead costs are not included for simplicity. It is estimated using the projected sales of 80 units in the first month.

[c.] The manufacturing costs are estimated using various product websites.

TABLE III: ESTIMATED ENERGY USAGE

Fridge Energy Usage Per Hour	**Energy Per Day**	**Energy Per Month**
0.8 kWh	19.20 kWh	576.0 kWh
Total Costs	3.46 BAM (1.90 USD)	103.68 BAM (56.96 USD)

[d.] This estimation is using the average cost of electricity of 0.18 BAM per kWh in BiH households.[10]

V. TIMELINE

6 MONTHS

Secondary Material Engineer Approval: The *Agfrost* crate cooling system require additional approval by a material engineer to calculate the system limits to ensure they are suitable to the required loads.

12 MONTHS

Manufacturing Prototypes and Negotiations: During this period, we will prototype the manufacturing process of the crates, form contracts to source materials, and distribute crates to buyers.

16 MONTHS

Trial at a Farm in Bosnia and Herzegovina: Our *AgFrost* containers will be trialed to various farms where any problems and inefficiencies will be monitored and documented during the summer.

20 MONTHS: REVIEW TRIAL AND IMPLEMENT NECESSARY CHANGES

Using the documentation and feedback from the trial, the product will be adapted to increase efficiency and resolve any problems. Another short trial will be conducted after.

24 MONTHS: RELEASE TO MARKET

Assuming the trials and final prototype doesn’t reveal any short-comings, sales will begin to farms across the country. Projected Sales are 80 in the first month.

26 MONTHS: ADVERTISING AND MARKETING

We will begin advertising and target small scale farms for summer produce cold storage on TV, radio and mail.

28 MONTHS: WINTER/SUMMER CRATE DESIGNING STAGE

This will entail further research into winter storage requirements, such as frost depth, and produce prototypes that can work year-round.

30 MONTHS: TRIAL WINTER/SUMMER CRATE AND RELEASE TO MARKET

46 MONTHS: INTERNATIONAL EXPANSION

Expand market to neighbors Serbia and Croatia.

The ABB robot often occupy space in factory lines for manufacturing of electronics, medical devices, food, cars, and other industries. They can perform various functions such as using suction, welding, and spraying.

VI. ABB Robot

Fig. 4. ABB Robot IRB 120

A. Operating the Robot

In order to jog the robot, the FlexPendant, a handheld operator, is used. To execute any programs written on the RobotStudio interface, the pendant needs to be used. Commands can be added manually with the operator itself as well.

B. Movements

MoveJ The robot moves to a fixed point, the path taken does not matter.
MoveL The robot moves linearly in the cartesian coordinate system.
MoveC The robot moves in a circle using two fixed points along an arc.

VII. Software: *RobotStudio 2023*

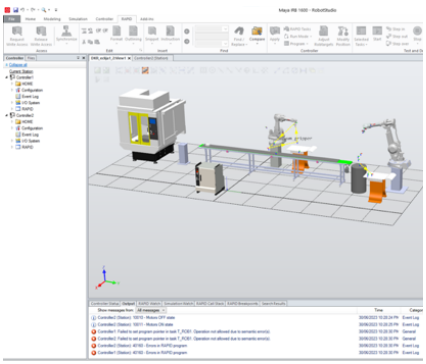

Fig. 5. RobotStudio Interface

RobotStudio is an offline programming and simulation interface.

A. Program Code

The ABB Robot was programmed to lift and move a box from one table to another using suction. A second program was used to move four boxes stacked on top of each other to four separate spots on another table. The following lines are examples of code from this project:

```
MoveAbsJ[[88.0384,0.0604724,5.1087,1.7059
9,83.3252,81.8554],[9E+09,9E+09,9E+09,9E+
09,9E+09,9E+09]],v1000,z30,tool0;
```

This line indicates the coordinates in space the tool should reach using a J movement. Then the speed is indicated with v1000, and the points of accuracy is specified with z30. Tool 0 is the suction tool name.

```
SetDO doHvataljka, 1;
```

This line turns on the suction tool.

```
SetDO doHvataljka, 0;
```

This line turns off the suction tool.

```
MoveJ offs(Pickup, 0, 0, 150), v1000, z50,
Gripper1;
```

This line uses offset from the defined constant, as seen in Appendix II, line .

```
MoveL Pickup, v1000, z50, Gripper1;
```

This line moves the tool to the location of the defined constant mentioned above.

Acknowledgments

Thank you to Professor Custovic for this collaborative learning opportunity. Thank you to Lilly Haley-Farr, Thomas Moore, and Callum Mackinnon for working on this project with me.

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[5] *Storage Guidelines for 16 Storage Crops Johnny's Selected Seeds*. Accessed Jun. 2023.

[6] H. Čustović, M. Ljuša, S. Schlingloff, *Sustainable Land Management – Approaches and Practices in Bosnia Herzegovina,* Sarajevo, 2020.

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[10] *Bosnia and Herzegovina Electricity Prices.* Global Petrol Prices, Accessed Jun. 2023.