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CFD ANALYSIS ON COLD STORAGE TO FIND OUT THE EFFECT OF DESICCANT MATERIAL ON RELATIVE HUMIDITY

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Abstract

Cold storage or refrigerated warehouses are facilities where perishable foodstuffs are handled and stores under controlled temperatures with the aim of maintaining quality. The study attempted to bring down the humidity as well as temperature within the best required range to keep the onions fresh for a longer period of time. A duct was added in the cold storage system. A desiccant material of blue gel silica is used to maintain the humidity and a fan is used to circulate the cold storage air. Both the desiccant material as well as fan was mounted inside the duct pipe. The results obtained were satisfactory and exhibited evidently in the study. For simulation 3 ton and 6-ton cold storage is selected for 2 cases. Simulation is done for checking the proper requirement of keeping onion, apple and potato for longer period. Humidity has wise impact on onion, for controlling humidity within the requirement range desiccant material (Blue silica gel) is used.

Keywords: Cold storage; desiccant material; humiditry; duct; desiccant air conditioning.

1. Introduction

India is one of the world's biggest fruit and vegetable producers; however, the losses of post-harvest production can reach up to 40% to 50%. Failure to store cold waste is a key factor in the high waste

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and must enhance food quality, quantity, and shelf life in order to satisfy the people's nutrition requirements. Hunger, particularly because of the vast number of underprivileged people across the country, is one of the most serious challenges facing Indian society. Some measures have been undertaken to create cold chains in India, however, the architecture of the cold chain is highly fragmented. But such problem cannot be solved alone by cold chain installations. Other difficulties include inadequate logistics, many food chain intermediaries causing low pay, poor post-harvest management and processing, and obsolete technology and infrastructure. However, if India exploits and exploits this potential through, among other things, the development of post-harvest management and the infrastructure of the cold chain, India will become the world's leading agricultural supplier [1].

1.1. Cold Storage

Cold warehouses are installations where foodstuffs that are biodegradable are kept under supervision in order for quality to be preserved. Food can be preserved under temperatures frozen or cooled. Apart from temperature, it may be necessary for numerous different commodities. [2] The cold store may be a location to protect them against being spoilt and to increase their preservation by various items like vegetables, fruits, medications, etc.

Cold storage design to be effective is an essential business requirement since poor style could lead to a loss and in certain circumstances might lead to a dangerous system operation. Apart from capital loss, because of degradation of product quality, there is also power loss and it is of the utmost significance to conserving as much electricity as possible in the country.

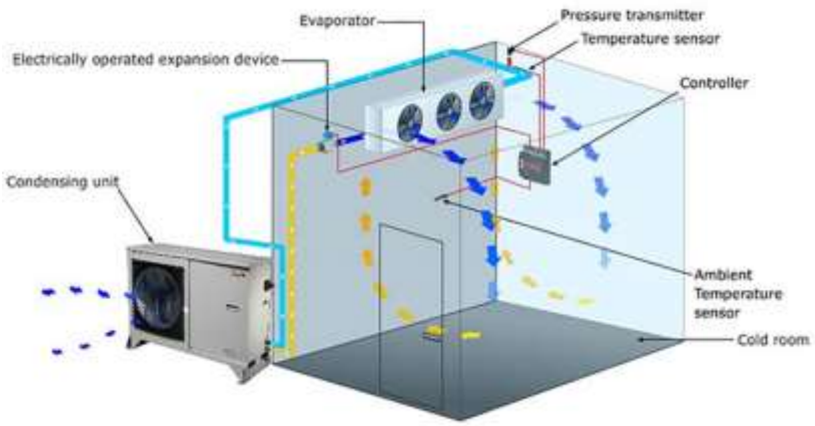


Figure 1: Cold Storage Room

1.2. Desiccant

Materials that are capable of attracting and holding other gases and liquids are often called sorbents. These sorbents are generally employed in chemical separation processes and used for the absorption of non-water vapour gasses or fluids. Desiccants are a subgroup of sorbents that exhibit water affinity in particular. This process of water vapor absorption and maintenance by the dryers is described as absorption/adsorption depending on whether or not the dry material undergoes a chemical modification when moisture is absorbed (adsorption). [3] In general, a desiccant draws 10-1100% of its dry water vapor weight, depending on the ambient humidity content and the type of material employed to dry. Even from dry air, dry matter continually attracts humidity until it finds a balance with the surroundings. The heating of the desiccant substance and exposure to a regeneration airstream removes humidity at temperatures between 50°C and 260°C. The desiccant should be cooled down after thoroughly drying, in order to draw water vapor again. Solid or liquid desiccants, particularly solid desiccants, and liquid desiccants are available. Adsorbents are mostly solids and liquids are absorbents. [4]

1.3. Motivation for DAC system

For the preservation/storage of agricultural goods, standard vapor compression refrigeration and/or air conditioning systems are utilized. In literature, such as environmental deterioration and energy needs, the drawbacks of traditional refrigerating systems are widely recognized. In addition to these drawbacks, traditional cooling systems cannot be utilized for storing on-farm plenty of tropical fruit and plants such as bananas, tomatoes, oranges, mangoes, and other green vegetables due to chilling injuries and colour degradation.

On the other hand, due to greater relative humidity, independent evaporative refrigerators cannot be employed in tropical climates. The desiccant air conditioning (DAC) system has the capacity to handle sensitive and latent air conditioning loads separately though. This contrast between the DAC systems offers a chance to utilize this system efficiently for the storage of agricultural products, both because of its temperature and relative humidity. [5] In this connection, temperature is the key element for maintaining product quality, given the direct dependency on the physiologic and biological processes in the goods. In order to preserve them in an excellent physical and biological look, relatively low humidity is also essential for limiting the loss of moisture content in items. [6]

1.4. Objectives of the Study

Following are the objectives of the present study, which are as follows:

- To study the effect of temperature distribution in cold storage by using desiccant material.
- The distribution of air will be study in cold storage.
- To calculate the relative humidity of the cold storage.

2. LITERATURE REVIEW

(Guo et al. 2020) [7] For the delay of the water loss of fresh products, the moisture control that is influenced by the humidification device's performance and container structure is very important. In order to assess the characteristics of humidity control through computational fluid dynamic (CFD) models, humidity rate and moisture distribution uniformity in the fresh storage container were examined. To measure the ventilation resistance of products, a pressure gauge was used to obtain inertial resilience and viscous resistance values. The moisture performance results were assessed using an entropy procedure. Results showed that a significant effect on the humidifying rate was the number of ultrasonic atomizers and sensor locations.

(Cengiz and Yilmaz, 2020) [8] In order to ensure the sustainability of the agricultural industry and reduce food loss, the widespread construction of cold storage buildings is important. However, because of financial difficulties, the number of cold warehouses in the majority of developing countries is not enough. At present, the payback period is the main incentive for investors to finance such projects. Data from selected cold storage studies in Turkey have examined the energy consumption and profitability of cold storage buildings based on their capacities. By simulation, the optimum storage capacity was estimated, and the link between payback times and cold stores capacity was evaluated using the data obtained.

(Qi, Dong and Zhang, 2020) [9] Dehumidification liquid desiccants may remove humidity from air supply independently. It offers several benefits, including excellent moisture management, use of low-grade thermal energy, increased air quality supply, and energy storage. This technology and its economic worth have become practical in practice with the progress of recent decades. However, because of the use of corrosive desiccants with limited heat capacity and insufficient weighting on packaging columns, the system still faces certain constraints. This study will assist to identify research gaps and explore novel ways of enabling liquid desiccant air dehumidification to become more feasible.

(Mohammed et al., 2019) [10] In order to study the process of thermal and mass transfer in the two heat exchangers, a mathematical model has also been constructed. For the validation of numerical findings, the experimental data collected are employed and excellent agreement is achieved. The impacts of DPHE and DCHE on the performance of the heat exchanger length and inlet circumstances are examined. The DPHE exceeds the DCHE's cooling capacity and moisture removal capacities in terms of experimental and numerical findings.

(Watanabe et al., 2019)[11] Appropriate moisture control can help to save electricity. But there are several weaknesses to the current dehumidification technology. Recently considerable interest has grown from the standpoint of decreasing energy use during dehumidification with liquid desiccant air conditioning. A systemic study of the humidifying capabilities of 16 IL types was performed to assess the adequate ionic liquids (ILs) as the desiccant for the liquid desiccant air conditioning system. Among the tested ILs, tributyl(methyl) phosphonium dimethyl phosphate ([P4441] [DMPO4]) exhibited the best dehumidification capacity and had a less corrosive effect on four types of metals as possible piping materials.

(Mishra and Aharwal, 2019)[12] Computational Flow Analysis Enable Large Cold Storage Air Distribution to be shown. Cold storage thermal performances are based on a closed chamber on airflow mechanism costly Cold Store Experimental Investigation. Thus, In This Paper the Impact of Auxiliary Draught systems (Ads) On Airflow Distribution Is Carried out with the Help of Computational Fluid Dynamics (CFD). 26 percent Error in the Simulation result is shown by experimental validation. The results reflect the use of ads, which decreases the cooling time by 25%. Auxiliary Draught provides the plant with a homogenous environment.

3. RESEARCH METHODOLOGY

3.1. Steps of working

- Design and modeling in CAD according to the experiment setup.
- Further converting the CAD File in .step format for importing it in Ansys Fluent work bench.
- Assigning the name selection to the different parts.
- Meshing for performing the simulation process.
- Providing the suitable boundary conditions according to the selected base paper.
- Assigning the material properties.
- Evaluating the results after the finish of simulation work.

3.2. Model Development

The cold store room used in this study is designed for a capacity of about 3 tons of onion preserved at storage temperature of 5 °C. The onions are arranged in two rows; each row contains 6 crates, built in column of about 2 m of height. Circulation corridors are provided between the different rows and near the walls. The table mentioned below shows the design parameters of cold storage.

Table 1: Design parameters of cold storages

S. No	Particular	Specification
1.	Cold Storage Length	2.8194m
2.	Cold Storage Width	2.6678m
3.	Cold Storage Height	2.5654m
4.	Crates along the length	2
5.	Crates along the Width	4
6.	Crates along the height	6
7.	Dimensions of the crates	0.54m x 0.36m x 0.29m
8.	Capacity of per crates	25 kg/crates
9.	Total capacity	1.2 MT

4. RESULTS AND DISCUSSION

4.1. Result Validation

RH is the most important variable affecting moisture components of the onion including moisture loss by fresh produce. The below graph represents the relative humidity in respect to the temperature. Both the results obtained from CFD as well as experimentation are exhibited. The results obtained for very similar and negligible difference can was reported. The maximum difference is when the temperature is 12°C which showed the value from CFD analysis and experimentation as 68.122% and 66.136% respectively. The experimental results were obtained from "Maulana Azad National Institute of Technology (MANIT), Bhopal, Madhya Pradesh".

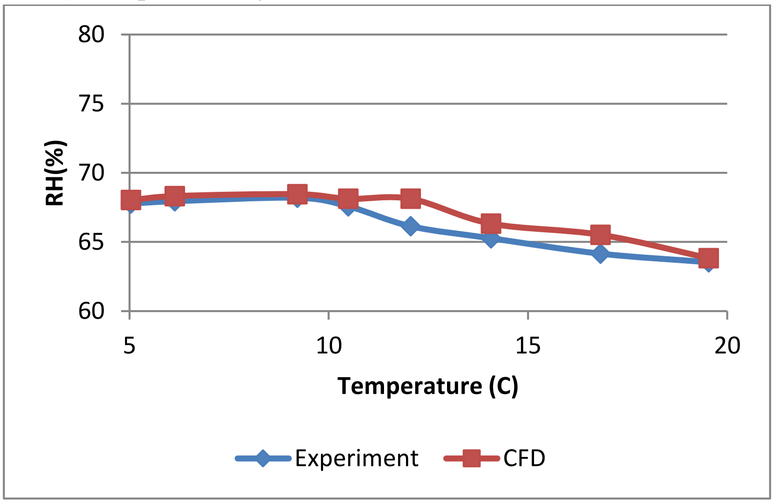


Figure 2: Validation graph of experimental and CFD study

4.2. Variation of Relative Humidity

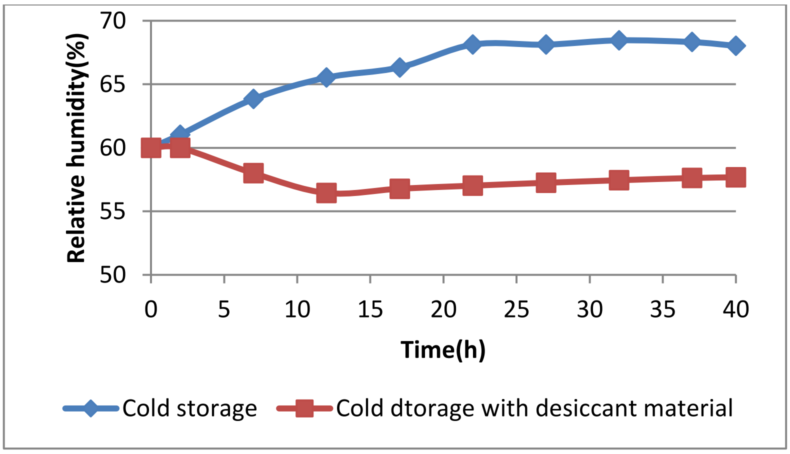


Figure 3: Comparison of Relative humidity of simple and modified cold storage from CFD analysis

4.3. Variation of Temperature

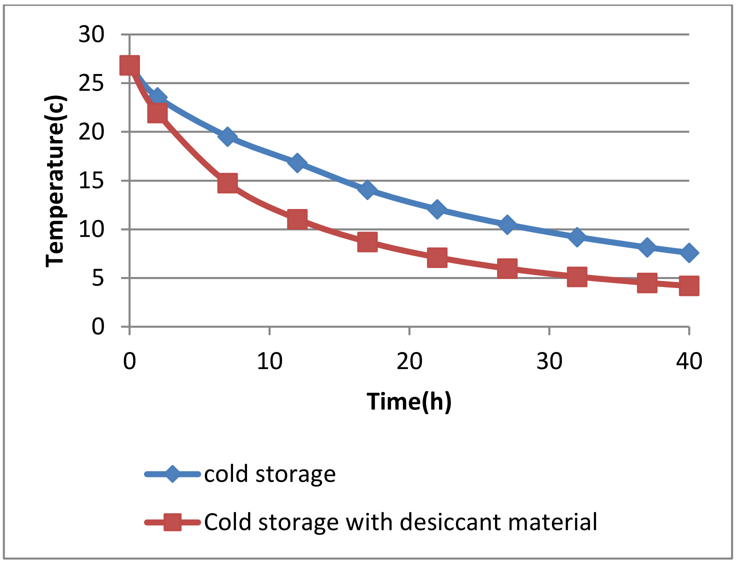
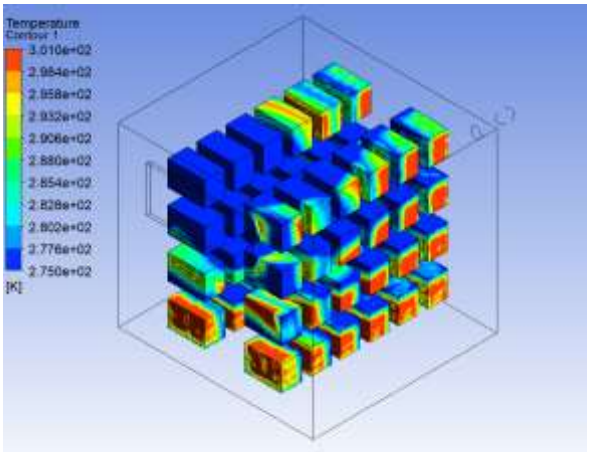


Figure 4: Comparison of Temperature of simple and modified cold storage from CFD analysis

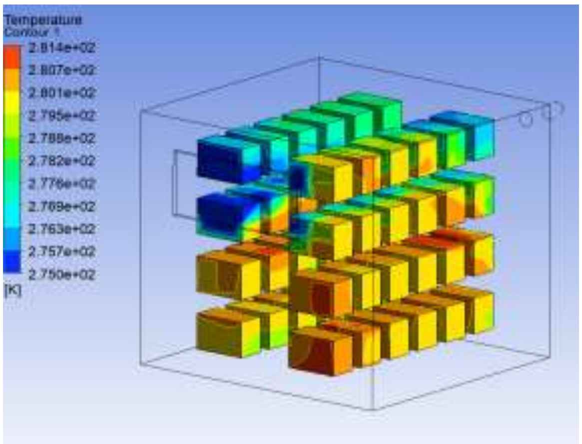
4.4. *Steady state result*

Case 1: Temperature variation among without desiccant, onion, apple and potato with 3 ton

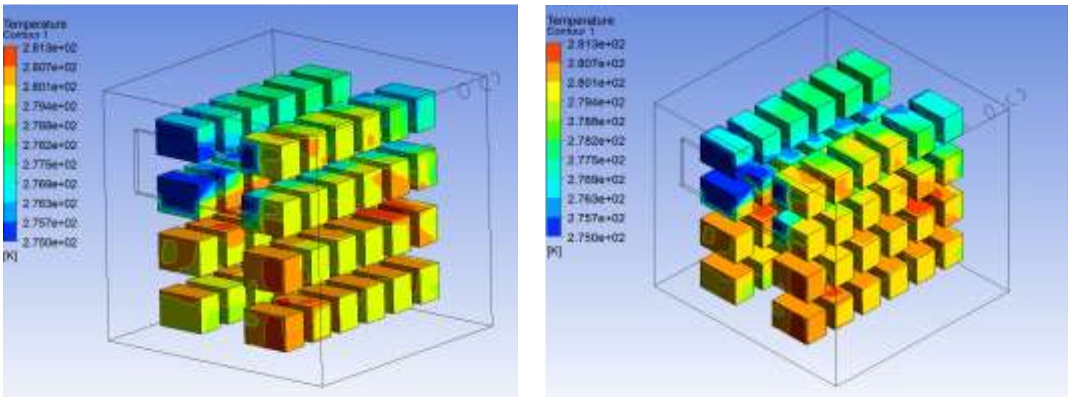
Temperature contour of all four different factors is shown in the figure given below for without desiccant, onion, apple and potato. Maximum temperature obtained for without desiccant, onion, apple and potato are 301.0K, 281.4K, 281.3K and 281.3K respectively. And minimum temperature obtained for without desiccant, onion, apple and potato is 275.0K for all.



(a)



(b)

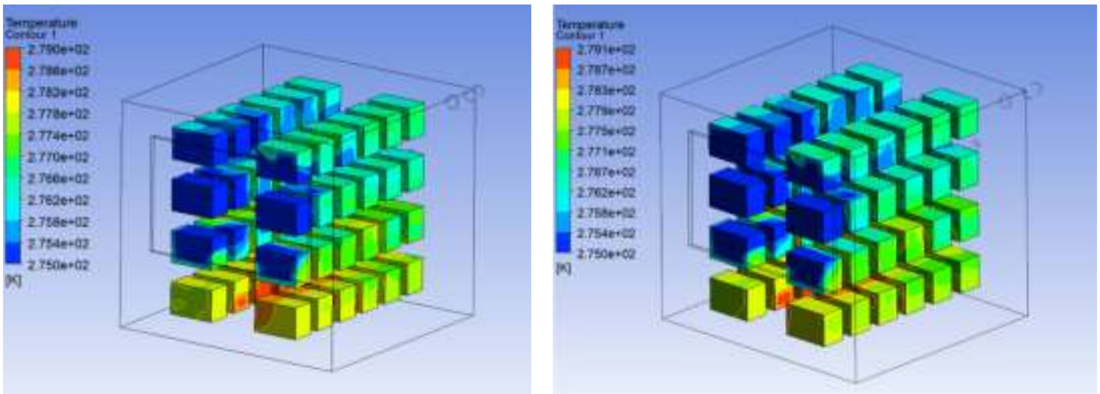


(c) (d)

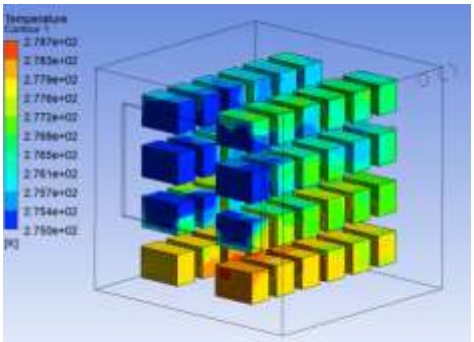
Figure 5: Temperature contour of (a) without desiccant, (b) onion, (c) apple and (d) potato in 3 ton refrigerator

Case-2: Temperature variation among onion, apple and potato with 6 ton

Temperature contour of all four different factors is shown in the figure given below for onion, apple and potato. Maximum temperature obtained for onion, apple and potato are 279K, 279.1K and 278.7K respectively. And minimum temperature obtained for onion, apple and potato is 275.0K for all.



(a) (b)

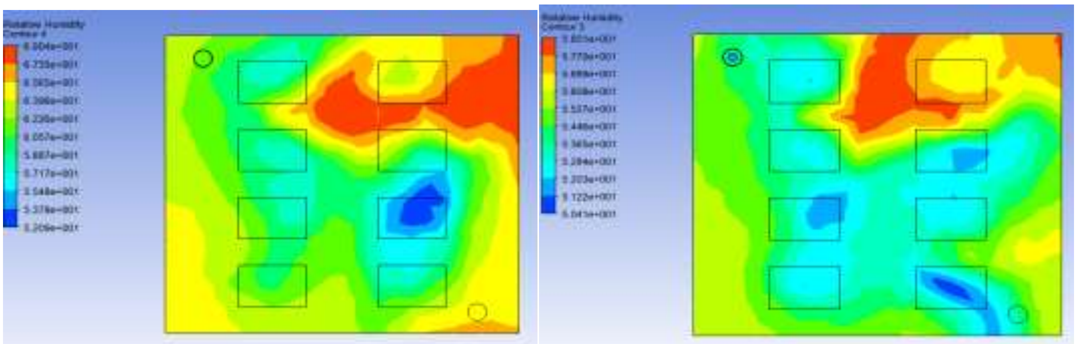


(c)

Figure 6: Temperature contour of (a) onion, (b) apple and (c) potato in 6 ton refrigerator

4.5. Humidity

As shown in figure 3a, it can be stated that the available humidity is recorded approximately as 70%. However, using the dessicant material brought the humidity within the required range, i.e. 60%, as shown in figure 3b.



(a) (b)

Figure 7: Humidity contour of (a) without desiccant, (b) with desiccant

4.6. 3 ton and 6 ton refrigeration

Below shown graphs shows temperature at different point inside cold storage in both 3 ton and 6 ton cold storage. By the graph it can be described that 6 ton refrigerator maintain much lower temperature as compare to 3 ton refrigerator. All 3 material follow the same trend 6 ton refrigerator is better for all materials; it can maintain low temperature and keep the materials fresh for longer period.

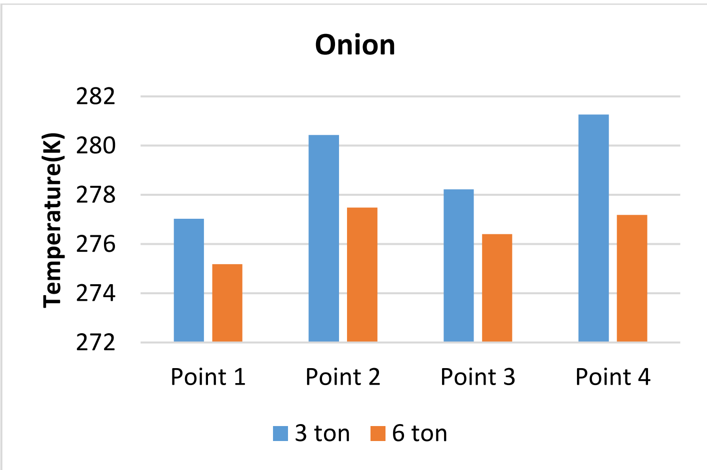


Figure 8: Temperature comparison of onion

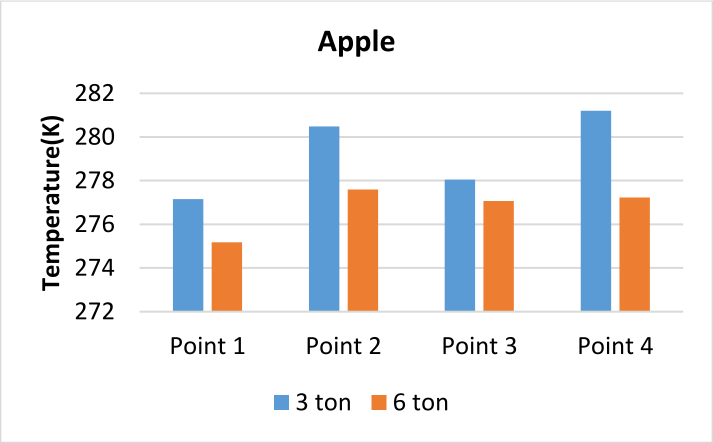


Figure 9: Temperature comparison of apple

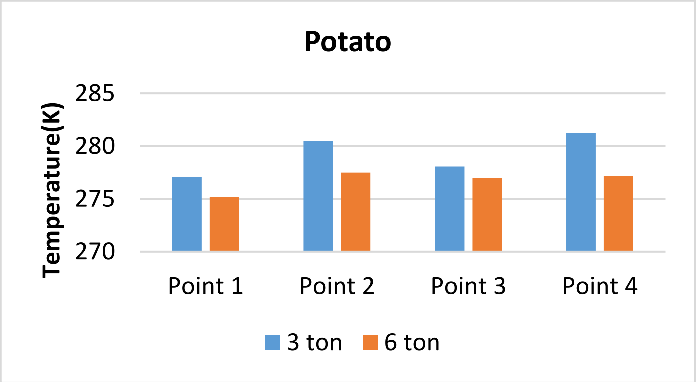


Figure 8: Temperature comparison of potato

5. CONCLUSION

This study was based on both experimental as well as CFD simulation. The used desiccant material brought down the humidity by a significant value. The maximum humidity required in a cold storage for storing onions is within the range of 55-65%. The results in this study showed that after using the desiccant material, the obtained humidity was 58.5%. This will help in storing the onions on a better required humidity and will keep the onions fresh for a longer time. Since the humidity content affects the quality of the onions, therefore this desiccant material can now evidently be used on larger scales. The fan used in the duct also reduced the temperature by a significant difference bringing down the temperature under the needed value i.e. 5^{o}C. The results showed the temperature of 4.623^{o}C which was attained because of using the fan in the duct. An approximate temperature attained with 6 ton capacity is 3-4 degree Celsius whereas with 3 ton capacity, 7-d degree Celsius temperature is attained. With the help of these results, it can be concluded that 6 ton capacity is capable of keeping the stored item fresher for longer period of time.

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