Thermal Studies of Fruits And Vegetable in Cold Storage by Using CFD Analysis

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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. Transfer of mass as well as heat transfer within the bags of onions is highly dependent over several parameters related to the operating conditions. This study is based on CFD simulations. The study attempted to bring down temperature within the best required range to keep the onions fresh for a longer period of time. 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, Temperature, Humidity, CFD Simulation, Refrigeration.

INTRODUCTION

Project design and project management of cold storage buildings are important aspects of sustainability. The proper use of resources is essential to sustain economic growth and reduce environmental impacts. [1] Cold storage is a key factor for worldwide food safety, which also affects the environment. According to the International Institute of Refrigeration, 475 million tons of perishable foods were spoiled in 2013 in developed and developing countries because of lack of refrigeration. [2]

Cold storages are the facilities wherever biodegradable food stuffs keep beneath control temperatures with the purpose of maintaining quality. Preservation of food can be done beneath frozen or chilled temperatures. For many alternative merchandise conditions aside from temperature could be needed.[3] Design of cold storage to be effective associated economic is a necessary criterion in business as ineffective style could result in loss and in some cases could result in unsafe operation of the system. Beside from the loss of capital due to degradation of quality of the products, there is also power loss and within the country like Asian nation, it becomes of greater importance to save the maximum amount of power as possible.

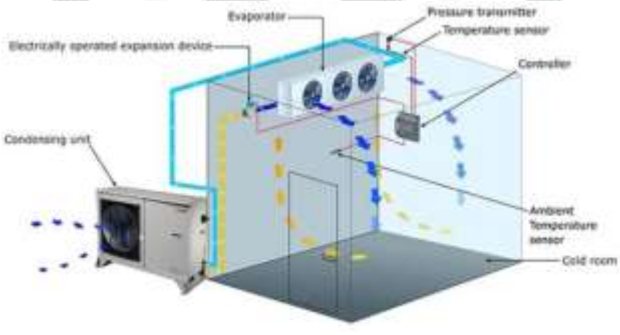


Figure 0: Cold Storage Room

Motivation for DAC system

The conventional vapour compression refrigeration and/or air-conditioning systems are being used for preservation/storage of agricultural products. The disadvantages of the conventional refrigeration system are well known in literature like environmental degradation and high energy requirements etc. Besides from these disadvantages, the conventional refrigerators cannot be used for on-farm storage of many tropical fruits and vegetables such as banana, tomatoes, oranges, mangoes, and other leafy vegetables because of chilling injuryand discoloration.

On the other hand, the standalone evaporative coolers also cannot be used in tropical climatic conditions because of higher relative humidity. However, the desiccant air conditioning (DAC) system has ability to deal with sensible and latent load of air conditioning distinctly. This distinction of DAC system gives opportunity to use this system for storage of agricultural products efficiently because both temperature and relative humidity are important for their optimal storage.[4] In this regard, the temperature is most important factor to maintain the quality of the products because the physiological and biological reactions in the products are directly dependant on it.[5]

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.

LITERATURE REVIEW

(Guo et al. 2020) [1] Humidity control, which is affected by the performance of humidifying device and structure of the container, is very important for delaying water loss of fresh products. Humidifying rate and humidity distribution uniformity in fresh-keeping container were investigated to evaluate the characteristic of humidity control by Computational Fluid Dynamics (CFD) models. A pressure gauge was adopted to measure the ventilation resistance of products, by which the inertial resistance and viscous resistance values were obtained. The results of humidity performance were evaluated by entropy method. The results showed that the number of ultrasonic atomizers and sensor location had a significant effect on the humidifying rate.

(Cengiz and Yilmaz, 2020) [6] Widespread construction of cold storage buildings is important to ensure sustainability of the agricultural industry and reduce food loss. However, the number of cold storage buildings in most developing countries is insufficient because of financial difficulties. Currently, the most critical factor for encouraging investors to finance such projects is the payback period. In this study, the power consumption and profitability of cold storage buildings were investigated based on their capacities using data from selected cold stores in Turkey. The optimal storage capacity was calculated by simulation, and the relationship between the payback period and the capacity of cold stores was analysed using the obtained results.

(Qi, Dong and Zhang, 2020) [2] Liquid desiccant dehumidification can independently remove moisture from the supply air. It has many advantages, including effective humidity control, utilization of low-grade thermal energy, higher supply air quality and energy storage potential. With the development in recent decades, this technology and its economic value are close to being viable in practice. However, the system still faces some limitations due to the use of corrosive desiccants with low heat capacity and insufficient wettability on packing columns. This paper firstly summarized the bottlenecks of liquid desiccant dehumidification in practical applications, including droplet carrying problems, low liquid/air contact area due to poor wettability, large temperature change during heat/mass transfer, and large heat requirement, etc.

(Mohammed et al., 2019)[7] Performance of two types of desiccant silica gel aluminum foam heat exchangers - desiccant coated heat exchanger (DCHE) and desiccant packed heat exchanger (DPHE) are evaluated experimentally and numerically. The DCHE is fabricated by coating silica gel over the ligaments of an aluminum foam, while the DPHE is built by packing an aluminum foam with silica particles. Equilibrium isotherms of the two heat exchangers are measured using the gravimetric approach. An open flow loop test rig is designed and built to measure the dry bulb temperature and humidity ratio of air upstream and downstream of the desiccant heat exchangers during the humidification and dehumidification process. In addition, a mathematical model is developed to investigate the heat and mass transfer process in the two desiccant heat exchangers. The experimental data obtained are used to validate the numerical results, and good agreement is established. The effects of heat exchanger length and inlet operating conditions on the performance of DPHE and DCHE are investigated.

(Watanabe et al., 2019)[8] Suitable control of the humidity can contribute to electric energy savings. However, the present dehumidification system has many weak points. The liquid desiccant air-conditioning system has recently gained growing interest from the stand point of reducing energy consumption during dehumidification. In order to find the appropriate ionic liquids (ILs) as a desiccant for the liquid desiccant air-conditioner system, a systematic evaluation of the humidification capability of 16 types of ILs was conducted.

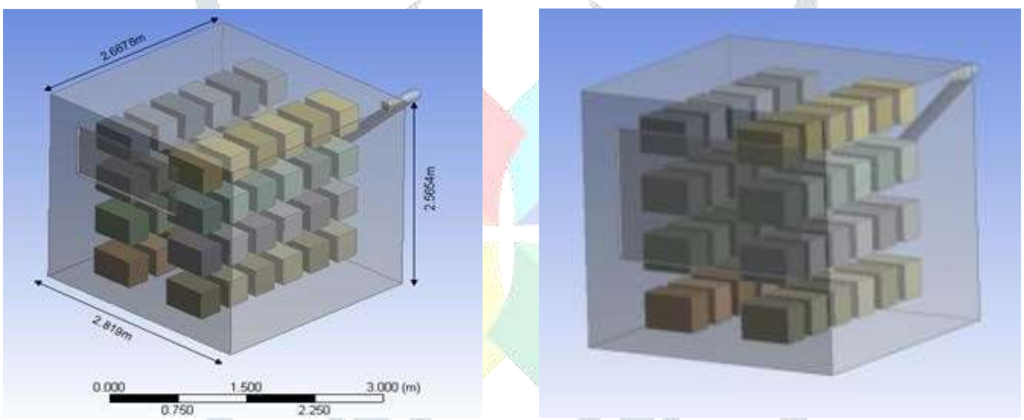
METHODOLOGY

CFD computer programs can be used to predict the airflow behaviour. In most cases, CFD is based on the solution of the approximate forms of the Navier- Stokes's equation, i.e., the Reynolds – averaged NS – equations (time averaged or ensemble averaged) or the filtered NS – equations, the energy equation, the mass and concentration equations as well as the transport equations for turbulent viscosity.

Dimensions of the cold chamber

(L x B x H) = (2.8194m x 2.5654m x 2.6678m)
No. of crates along the length = 2 No. of crates along the width = 4 No. of crates along the height = 6
Total no. of crates in the cold chamber = 2 x 4 x 6 = 48 cratesDimensions of the crates
(l x b x h) = (.54m x .36m x .29m) Capacity of per crates in kg = 25 kg/crates.
Total capacity of the chamber = Total no. of crates x storage capacity of 1 crates
= 48 x 25 = 1200 kg
= 1.2 MT
Air circulation during study state (CMH/MT of produce) = 60 CMH/MT
Flow capacity of the evaporator = storage capacity of chamber x air circulation (CMH/MT)
= 1.2 x 60 = 72 CMH
Air flow velocity from the evaporator fan = 1 m/s

Design



(a) 3 ton (b) 6 ton

Materials Used

Onions: The onions were harvested each year in August, and stored for a period of one year in a cold room (4). For experimentation, onion was kept in the modelled cold storage room. The dry matter content of onions stored for one year was 3% lower than that of freshly harvested [9]. To maintain quality of onion, humidity should be maintain approximately 60%.

Apple: Apples have the longest storage life of the tree fruits, and can be kept in cold storage up to four months under ideal conditions and up to 12 months in controlled atmospheres. Apple requires to maintain 3 to 4 °C temperature in cold storage.

Potato: Potato can be stored in cold storage for longer period. For potato storage, cold storage should be maintained between 2-4 °C.

Material	Density(kg/m^3)	Specific heat(J/KgK)	Thermal conductivity(($Wm^{-1}K^{-1}$))
Onion	970	4010	0.54
Apple	845	3640	0.427
Potato	1100	3600	0.5

Blue Silica Gel: In accordance of the results obtained from this study, blue silica gel has absorbed approximately 8% percent of its weight in water the coloured crystals will turn from blue to pink making an easy visual indicator of whether the gel has become saturated with moisture.

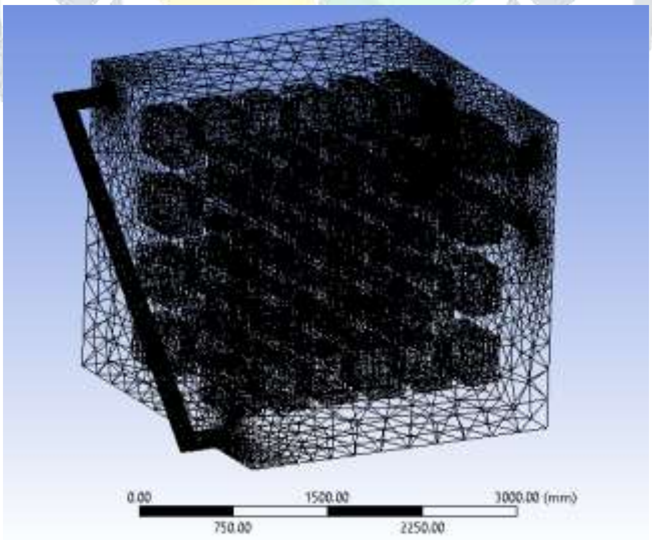
TECHNICAL SPECIFICATION As per IS-3401-1979/1992/2003	
DESCRIPTIONS	SILICA GEL BLUE
Type	Indicating Type
ASSAY (as SiO_2)	97 – 99 %
pH	6-7
Bulk Density	0.600 - 0.700 gm/cc
Loss on Drying %	< 5-6 %
Loss on Attrition %	2.5%
Adsorption Capacity at 100% humidity	27 – 40 %
Friability	99.5
Chloride (as Nacl)	0.4 ppm
Sulpates (Na_2SO_4)	0.5 ppm
Ammonium (NH_3)	NIL
Particle size (Mesh)	1-2,3-4, 3-8, 5-8, 9-16, 16-30
Chemical Formula	$SiO_2+H_2O+CoCl_2$

Steps of working

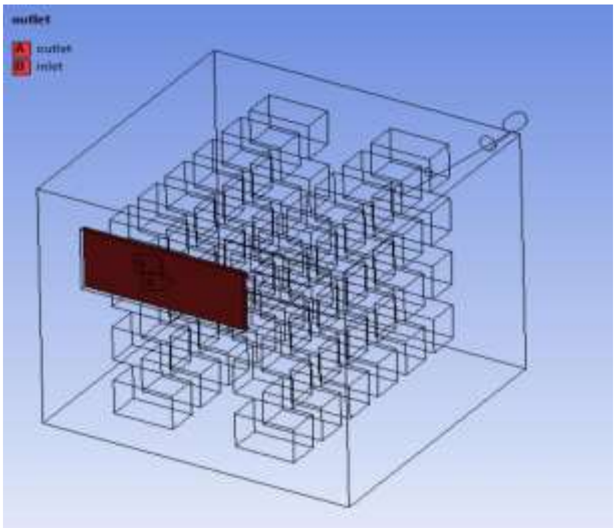
- Design and modeling in CAD according to the experiment setup.
- Further converting the CAD File in .step format for importing it in Ansys Fluent work bench.
- Assigning the name selection to the different parts.
- Meshing for performing the simulation process.
- Providing the suitable boundary conditions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

Meshing

Meshing is an important factor in CFD simulation. Meshing splits down design into nodes and elements for better formation of results. In this case meshing splits the design into 213735 elements71840 nodes as shown in below figure. In cold storage section tetrahedral meshing is used and for the onion or other material placement design quadrilateral meshing is used.



Name selection



Numerical solution

The commercial CFD code ANSYS Fluent 2021 R1 based on finite volume approach was used for the numerical implementation of the model with steady state flow. Turbulence (k and ε) transport equations were used with energy equation ON. For calculation of humidity, Multiphase model was used where the fraction of air and water is defined.

RESULTS AND DISCUSSION

Case 1: Temperature variation without desiccant, among 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.

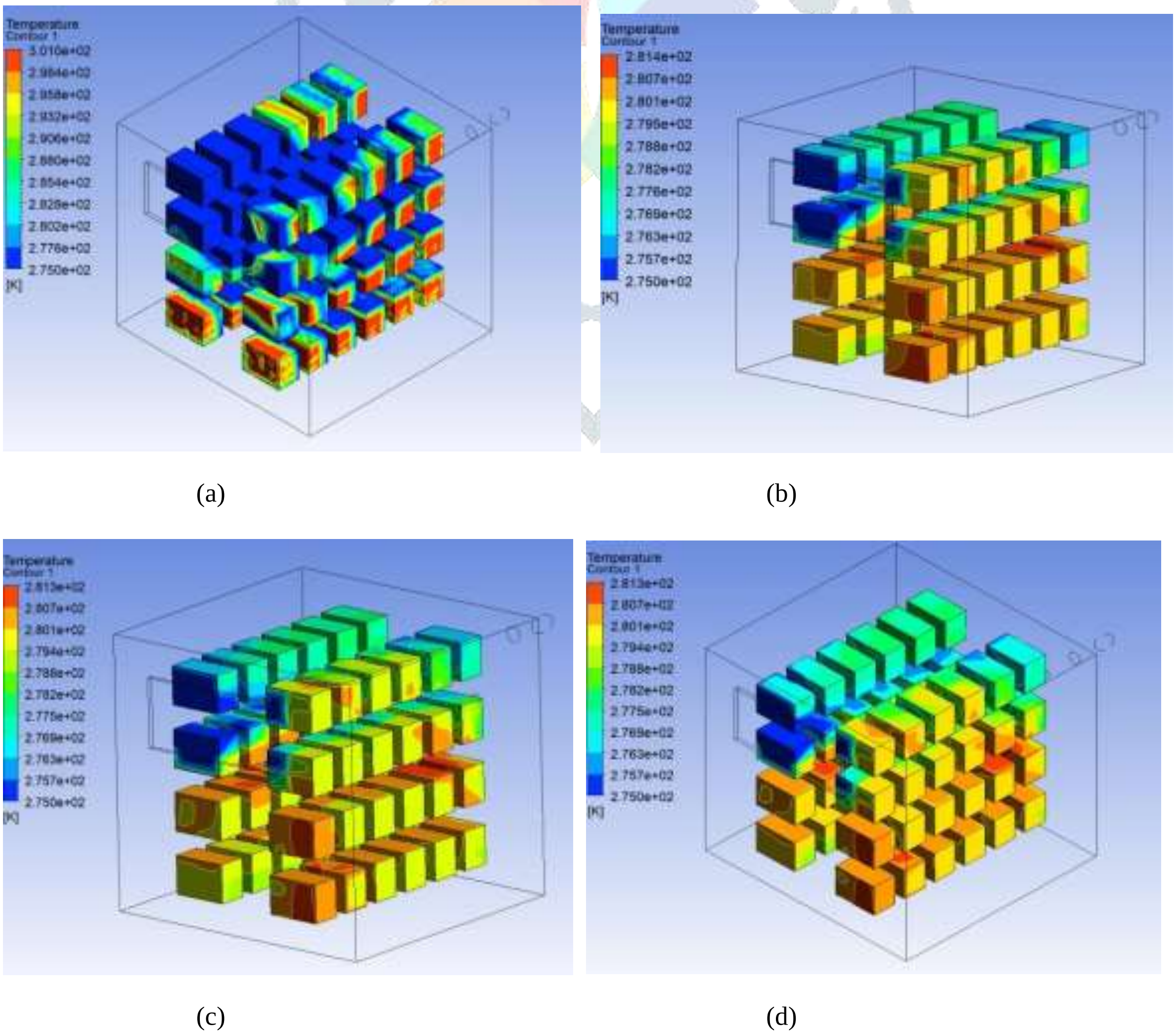
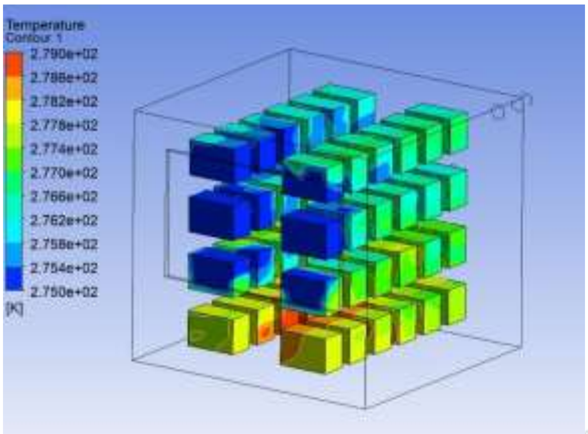


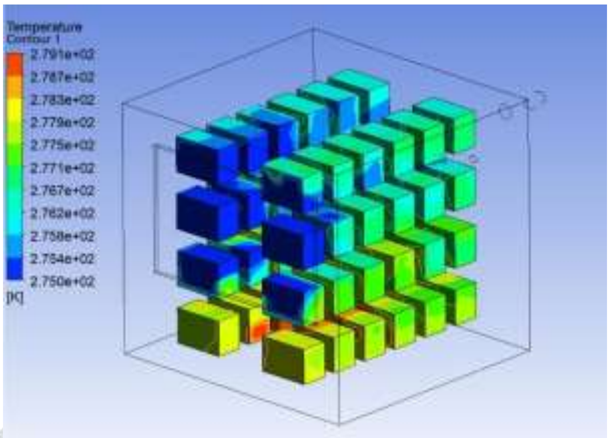
Figure 2: Temperature contour of (a) without desiccant, (b) onion, (c) apple and (d) potato in 3 ton refrigerator

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

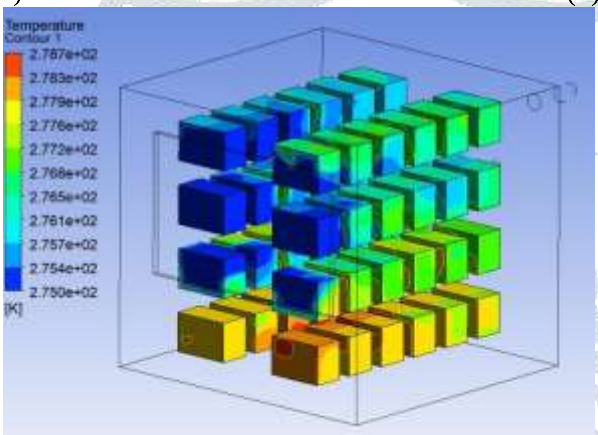
Temperature contour of all four different factors is shown in the figure given below for onion, apple and potato. Maximum temperature obtained for onion, apple and potato are 279K, 279.1K and 278.7K respectively. And minimum temperature obtained for onion, apple and potato is 275.0K for all.



(a)



(b)

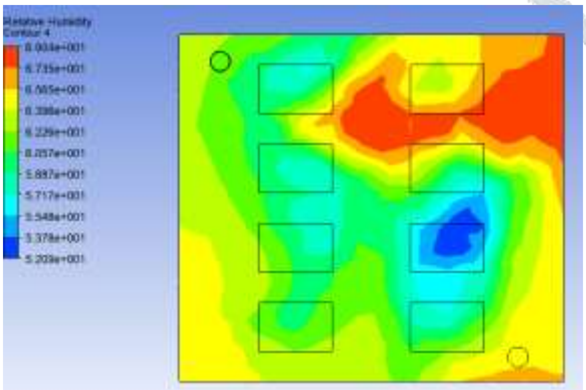


(c)

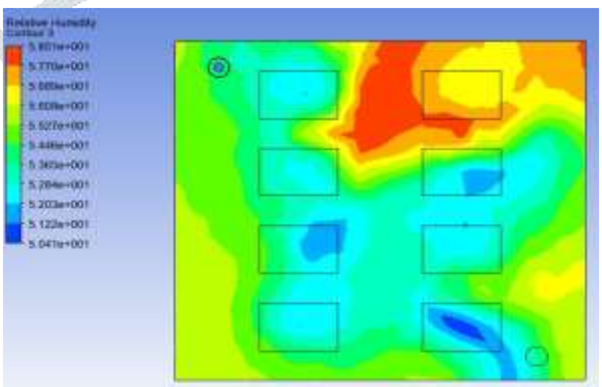
Figure 3: Temperature contour of (a) onion, (b) apple and (c) potato in 6 ton refrigerator

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)

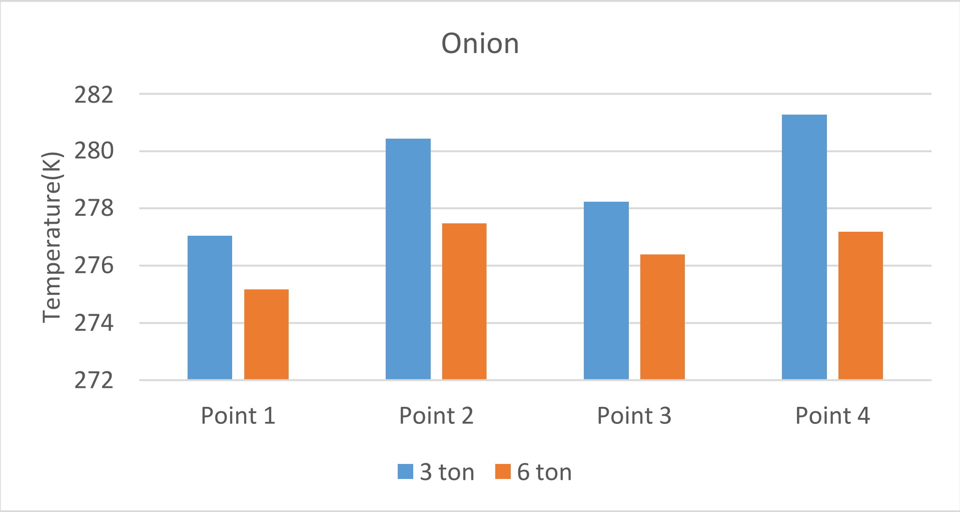


(b)

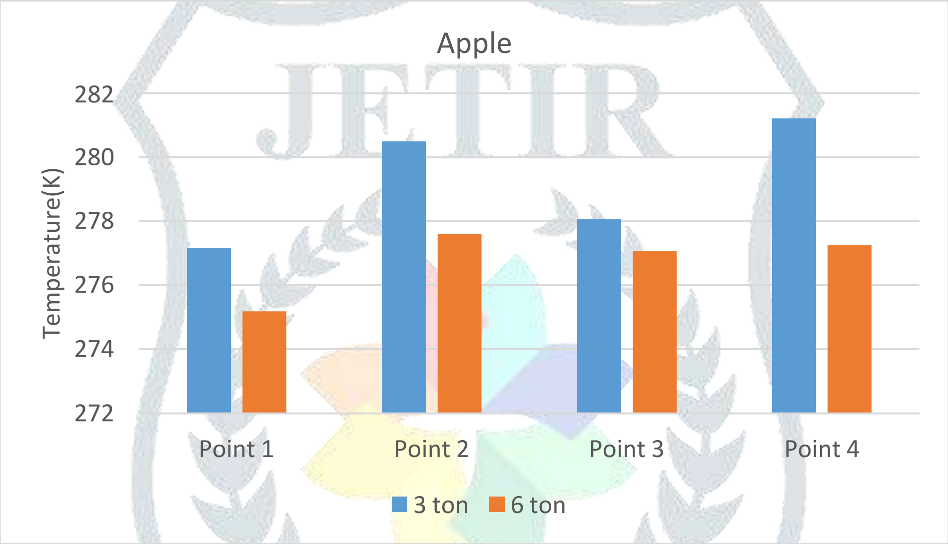
Figure 3: Humidity contour of (a) without desiccant, (b) with desiccant

Temperature comparison of onion in 3 ton and 6 ton refrigeration

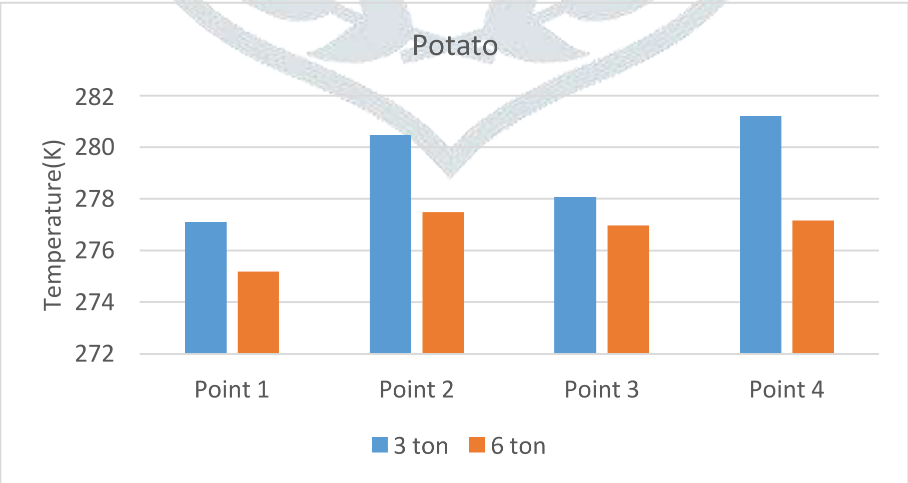
Below shown graphs shows temperature at different point inside cold storage in both 3 ton and 6 ton cold storage. By the graph it can be described that 6 ton refrigerator maintain much lower temperature as compare to3 ton refrigerator. All 3 material follow the same trend 6 ton refrigerator is better for all materials, it can maintain low temperature and keep the materials fresh for longer period.



Temperature comparison of apple in 3 ton and 6 ton refrigeration



Temperature comparison of Apple in 3 ton and 6 ton refrigeration



Temperature comparison of potato in 3 ton and 6 ton refrigeration

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 required temperature range for the cold storage is within 3-4 degree Celsius. The temperature attained in all the cases were less for six ton capacity in comparison to that of 3 ton capacity. 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. Using desiccant material reduced the humidity and brought it within the required range of 60-65%.

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