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Research Article

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Evaluation of Ambient Temperature and Relative Humidity Distribution in Empty Cold Store with Chiller

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Abstract Properties of the ambient conditions in cold storage are very important for cold stored products. The homogeneity of storage environment conditions increases the storage time of stored products. The differences between the ambient temperature and relative humidity values were measured for different Y axis and levels (top, medium, base) for empty cold store with chiller unit. Spatial variability was tried to be determined at different levels. According to the results; mean temperature and relative humidity was measured as 2.82°C and 87.86% for top, 2.81°C and 88.24% for middle level and 2.82°C and 87.93% for base level in the empty cold storage. There isn't big differences between levels in the experimental cold store with chiller. All the results showed that distribution of the ambient temperature and relative humidity were less than the conventional cold stores which has evaporative cooling system.

Keywords cold storage, chiller, ambient temperature, relative humidity

1. Introduction

The reason of this research is irregular distribution of cold air in the cold store. Differences in the ambient temperature and relative humidity have negative effects on the quality of the stored products. These irregularities cause quality and quantity losses in cold stored products. In practice, modern humidification systems are used rarely in the cold stores. Conventional humidification such as wetted nuts, water spraying by hand on surface or watering in aqua containers) have been used. The conventional humidification methods causes uneven distribution of the ambient the temperature and relative humidity Uneven distribution of the storage conditions cause quality loss and deterioration in the stored product.

There is a direct relationship between moisture content and product quality in cold air storage during storage. For this reason, it is important to make the homogeny humidification in the cold stores. Heterogeneity in humidification is inevitable as commercial cold storage warehouses manufactured in large sizes. Temperature and humidity (vapour pressure difference) gradients between two media contacted with each other was gradual. The water-giving product first attempts to fill the air layer nearest to its surface. As a result, the vapour pressure gradually increases in the form of a hyperbolic curve. The air current removes the closest and most saturated air layer to the fruit, replacing the most unsaturated air mass. For this reason water loss from the crop increases significantly compared to the stagnant weather conditions [1].

The purpose of the study is to determine the differences in storage temperature and relative humidity for different layer in the cold store with chiller unit. Our hypothesis is that "if the ambient temperature and the local variability in relative humidity are reduced, the quality loss of the stored product will be less".

2. Review of the Literature

The amount of the losses and quality changing of cold stored agricultural products in a cold store is very much dependent on the temperature fields which are highly related to the air flow fields [2] designed a twodimensional mathematical model in a model cold room and developed a computer program. Simulation results reflect the characteristics of air velocity and temperature distribution. After that, the parameters affecting the flow field (corners, product stack) were analysed. The results have shown that the product stack is particularly influenced by flow and temperature.

A modelling method for simulating heat and mass transfer in cold storage of orchard products has been developed. This method is used to estimate the mass transfer of water vapour of packaged garden products. Heat transfer paths considered to be the most important factor for the packaging system were modelled. Experimental tests were conducted for 10 product packaging systems. Single-zone packaging was found to be sufficient in all tests, although the model supports multi-zone packaging systems [3].

A model has been developed for the estimation of latent heat, audible heat, moisture losses and temperature distribution in bulk storage of fruits and vegetables. The porous media approach has been applied to model respiration, sweating, convective heat and mass transfer.

Temperature, air velocity and relative local variability of floor, centre and ceiling planes were determined in an experimental cold room, [4]. Maps and descriptive statistics were used to show the spatial variability.

In order to maximize the efficiency of food cooling and freezing processes, it is necessary to optimize the design of the appropriate refrigeration equipment required for refrigeration and freezing. The cooling time must be determined depending on the cooling load in the design of the cooling equipment. Accurate estimation of these factors depends on precise determination of surface heat transfer coefficients for cooling and freezing operations. In order to determine the surface heat transfer coefficients, a cooling curve of 295 different foods were obtained by an industrial survey [5].

Investigations have been made on an ultrasonic humidifier used for unpacked fruit and vegetables sold at retail. In this research study, the products and equipment were compared with the 7 day tests. Experiments have compared fogging and non-steady methods. No significant difference was found in average product temperature. However, there are minor differences in the cooling performance of the cooling cabinet (in terms of ambient temperature and cooling effect). It has been determined that moisturizing reduces weight loss in all products. It was also found that the moisture loss on the stored products decreased. The microbial quality of the products has not been adversely affected by moisturizing. There was a slight increase in airborne micros in the case of wet fogging, but there was no statistical difference between the two applications [6].

The airflow in a cold room was investigated using CFD (computational fluid dynamics). The airflow pattern is made according to the conditions accepted as permanent and incompressible. Turbulence was taken into account using the k-ε model. The forced air circulation of the refrigerant unit was modelled in accordance with the approximate body strength and resistance associated with the characteristics of the evaporator air duct and fan. The validity of the model was calculated by comparing the calculated time-averaged speed values with the sensor values measured everywhere. The relative error of air velocity was observed to be 26% [7].

In a study; it was aimed to optimize and improve air distribution systems in refrigerated vehicles to reduce temperature differences across the entire palletized cargo. This condition is essential to protect the shelf life, quality and safety of perishable foods. Experiments were carried out in a reduced model of cooling devices (1:3:3). Performance related to ventilation and temperature homogeneity was characterized by a system with and without air channels. These two systems are widely used in trucks with refrigerant systems. Numerical modelling of the airflow was performed using Computational Fluid Dynamics (CFD) and Reynolds Stress model (RSM). The results obtained using the RSM showed good agreement with the experimental data. The modelling results and the experimental results clearly show that the temperature decreases between the cargoes in air-blown systems through the pipe [8].

3. Materials and Methods

3.1. Cold store

The cold store was 4 x 5 x 3 m in size. It was located in Namik Kemal University (NKU), Tekirdag. This cold store has a cooling system with chiller and the air has been cooled in the external unit before being blown onto the fruits through ducts. Polyurethane sandwich panel were used for the construction of the walls. After the construction of the building, all the walls and floors of the cold depot were formed with prefabricated sandwich panels filled with polyurethane. Panel thickness is 80 mm. The polyurethane thermal conductivity coefficient is 0.025 W/mK according to DIN 4108. Both surfaces of the wall and ceiling panels are 0.50 mm thick, galvanized sheet painted with polyester based paint. The floor panels are covered with stainless steel sheet with a thickness of 0.50 mm on the imported plywood with 9 mm thickness on the inner surface and galvanized with 0.50 mm thickness on the outer surface and filled with 80 mm polyurethane. Then the sliding door was installed. The door surface is in the same direction as the panel surfaces (Figure 1).

Figure 1: Cold store general view

The cooling system consists of a water chiller, air cooling group, air conditioner, suction and discharge channels, and suction and discharge vents.

Water cooling; Technical characteristics are shown in table 1 and the general view of the group is shown in Figure 2 with water cooled by R404a refrigerant in the water cooling group.

Table 1: Technical specifications of water cooling unit

Compressor model	HGX 34P/215-4S Semi- Hermetic Cylinder type
Evaporator / compressor temperature	0/+40°C
Capacity	15 kW
Compressor power	4.59 kW
C.O.P	3.27
Water inlet/outlet temperature	10°C /6°C
Refrigerant	R 404A

Air conditioning device: The technical features of the air conditioning device are given in Table 2 and Figure 2.

Table 2: Technical specifications Air-conditioning unit

Ventilator type	Axial
Air flow rate	8.000 m^3/h
Cooling unit capacity	10 kW
Heat capacity	5 kW
Inlet Air temperature/relative humidity (%)	19°C / 65% RH
Outlet air temperature/relative humidity (%)	15°C 85%RH
Water Input/output	6/11°C
Heating type	Electrical resistance
Ventilator air flow rate	Adjustable with inverter

Figure 2: Air-conditioning unit, suction and pressure channels

The water cooled in the water cooling group provides cooling of the air in the cooling battery in the air conditioner. Cooled is blown into the discharge air channels at desired temperature and relative humidity values.

Suction and pressure air channels: Air channels of ventilation device (air handling unit) is made of galvanized steel (Figure 8). In order to distribute the conditioned air coming from the discharge channels and to allow exhaust air for suction. in the cold store, three pressure vents and three suction vents were located on the ceiling of the cold store. All of this construction was in a closed loop to ensure that the air is sent to the cold store at the desired temperature and relative humidity and to take back the exhaust air. In Figure 4-a, suction bores are shown, in Figure 4-b the location of the bores were given.

Establishment of the humidifier: A humidifier which its capacity was 2 kg/h steam was located in the cold room. The humidification requirement is provided by a sprayer placed in the discharge port.

Electric Control Box; The electric control panel has internal locks, fuse, contactor, relay, lamp, switch, ampermeter etc. (Figure 3).

Automatic control in the cooling system: With the microprocessor digital control panel, the heating, cooling and humidification processes have been realised in order to distribute air at the desired temperature values into the cold store. If there is any uncontrolled overheating in the heating system, the whole system can be stopped and the alarming function was activated.

Figure 4 shows the representation of the room with the control panel. Temperature and relative humidity values can be read and set values can be changed from here, PID control of the system was realized by digital panel.

Figure 3: Electrical control box

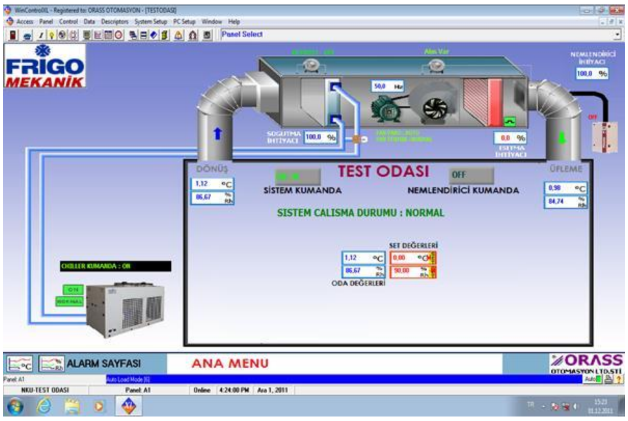

Figure 4: Automatic control system of the cold store

3.2. Temperature and relative humidity sensors

Temperature Sensors: Testo 177 H1 data logger was used to measure temperature at same time and same point [9]. Measurement ranges of the TESTO 177-H1 was between -20 ° C and + 70°C for temperature and 0%...and 100% for relative humidity (Figure 5).

Figure 5: Testo 177 H1 data logger

3.3. Methodology

Ambient temperature has been set to +1°C and relative humidity set to 90 %. Spatial distribution of temperature was used by Testo 177 H1 data logger. The data were measured from 3 different Y axis at 3 levels for 4 points (Figure 6). Total number of the measurements was 36 points

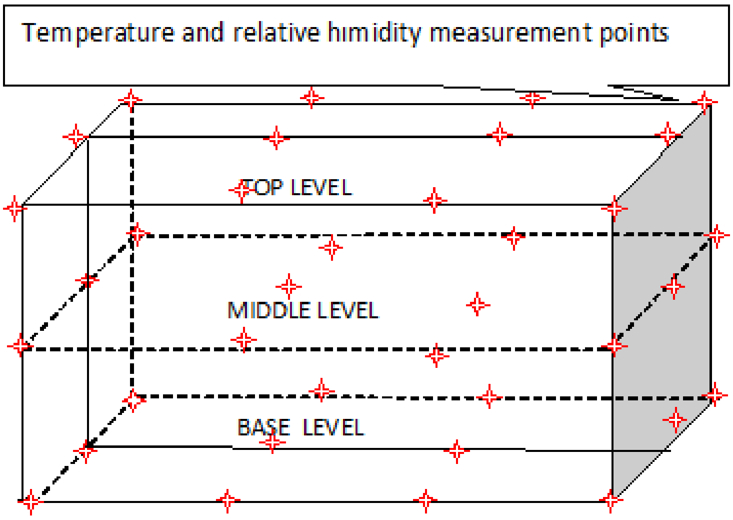

Figure 6: Measurement points in the cold store

The Y planes were called as 1, 2, 3, and 4 (Fig. 10 a) and Z plane were called as top, middle and base in the variance analysis and evaluations (Fig. 10 b). In the evaluations obtained in the measurements, the planes in the Y axis and the planes in the Z axis were considered.

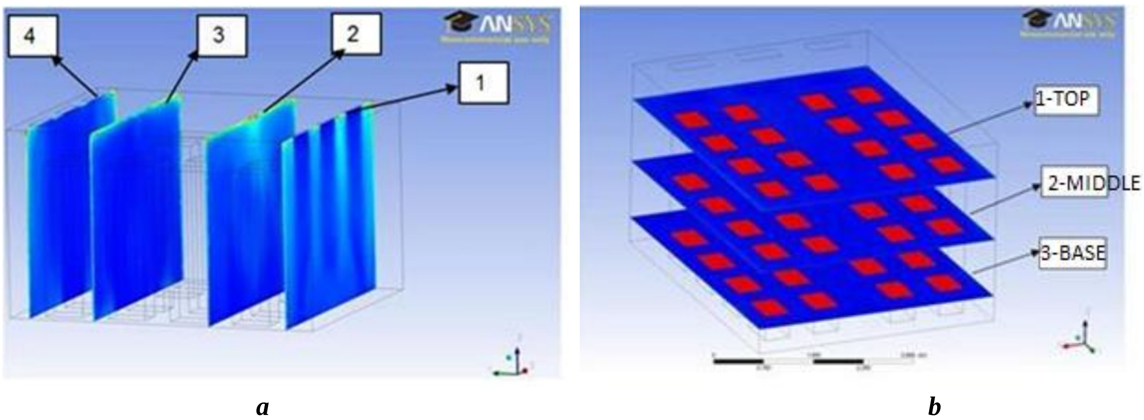

Figure 7: Planes and its codes for Y axis (a) and Z axis (b)

Temperature and relative humidity measurements realised for empty cold storage. The cold store worked for 24 hours. Testo 177H1 data logger measurement frequency was 1 minute. Mean values of ambient temperature (t_{mean}, ^oC) and relative humidity (RH_{mean}, %) were calculated from 1440 data from 36 sensors. Descriptive statistics such as mean, minimum, maximum, standard deviation and coefficient of variation were calculated from measured data [10].

4. Results and Discussions

Results of temperature and relative humidity measurement for empty cold store were given in Table3. When the results of the investigated; mean, standard deviation and coefficient of variation value of the ambient temperature were determined as 2.82 ^OC, 0.02 ^OC and 0.62 %, respectively. Mean, standard deviation and coefficient of variation of relative humidity were calculated as 88.0%, 0.61% and 0.70%, respectively.

Mean values of ambient temperature and relative humidity for different levels were given in Table 4 and for Y-axis in Table 5.

Table 3: Mean ambient temperature (^oC) and relative humidity (%)

	Y-levels	Z levels	t_{mean} (^oC)	RH_{mean} (%)
	1	1	2.83	87.43
	1	2	2.80	87.67
	1	3	2.83	88.13
	2	1	2.83	88.23
	2	2	2.83	89.57
	2	3	2.83	87.47
	3	1	2.83	88.07
	3	2	2.80	87.47
	3	3	2.80	88.53
	4	1	2.80	87.70
	4	2	2.80	88.23
	4	3	2.80	87.60
Mean			2.82	88.01
Minimum			2.80	87.43
Maximum			2.83	89.57
Standard deviation			0.02	0.61
Coefficient of variation (%)			0.62	0.70

Mean temperature and relative humidity was measured as 2.82^oC and 87.86% for top, 2.81^oC and 88.24% for middle level and 2.82^oC and 87.93% for base level in the empty cold storage. There isn't big differences between levels.

Table 4: Mean values of ambient temperature and relative humidity for different levels

Levels	Mean temperature (^oC)	Mean relative humidity (%)
Top	2.82	87.86
Middle	2.81	88.24
Base	2.82	87.93

Table 5: Mean values of ambient temperature and relative humidity for Y axis

Y Axis number	Mean temperature (^oC)	Mean relative humidity (%)
Y-1	2.82	87.74
Y-2	2.83	88.42
Y-3	2.81	88.02
Y-4	2.80	87.84

The results show that mean ambient temperature and relative humidity changing for Y axis was not so big. It is good for cold storage of agricultural products because spatial variability of the ambient conditions will be small.

5. Conclusions

The cold store with chiller was different than conventional cold stores which has evaporative cooling system. Conventional cold stores includes compressor, condenser and evaporator. The cold store used in this research has chiller unit and air distribution system into the cold store. The results showed that distribution of the ambient temperature and relative humidity of the cold store with chiller unit was very good. If the results compare cold store with evaporative cooling system, ambient temperature of the cold store at 1°C storage set up temperature was changed between 1.5°C and 3.9°C for evaporative cooling system, 2.80°C - 2.83°C for cold store with chiller unit. The relative humidity was changed between 81.1 % and 95 % for evaporative cooling system [11] and 87.43% -89.00& for cold store with chiller. All the results showed that distribution of the ambient temperature and relative humidity were less than the conventional cold stores which has evaporative cooling system

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References

[1]. Karaçalı, İ. (2009). *Conservation and marketing of garden products.* (7th Edition). Ege University Agriculture Faculty Pub, 5th Ed.,(486)

[2]. Xie, J., Xiao-Hua Qu, A., Jun-Ye Shi, A., and Da-Wen, S. (2006). Effects of Design Parameters on Flow and Temperature Fields of a Cold Store by CFD Simulation. *Journal of Food Engineering*, 77(2): 355-363.

[3]. Tanner, D.J., Cleland, A.C. and Robertson, T.R. (2002). A Generalised Mathematical Modelling Methodology for Design of Horticultural Food Packages Exposed to Refrigerated Conditions: Part 3, Mass Transfer Modelling And Testing. *International Journal of Refrigeration*, 25: 54–65.

[4]. Akdemir, S., and Arin S. (2005). Effect of Air Velocity on Temperature in Experimental Cold Store. *Journal of Applied Sciences*, 5(1): 70-74.

[5]. Becker, B. R., and Fricke, B. A. (2004). Heat Transfer Coefficients for Forced-Air Cooling and Freezing of Selected Foods. *International Journal of Refrigeration*, 27: 540–551.

[6]. Brown, T., Janet, E.L. C., and Stephen, J. J. (2004). Humidification of Chilled Fruit and Vegetables on Retail Display Using an Ultrasonic Fogging System with Water/Air Ozonation. *International Journal of Refrigeration*, 27(8): 862-868.

[7]. Hoang, M.L., Verboven, P. De Baerdemaeker., and J. Nicolaoe, B.M. (2000). Analysis of the Air Flow in a Cold Store by Means of Computational Fluid Dynamics. *International Journal of Refrigeration*, 23: 127-140.

[8]. Moureha, J., and Flick, D.B. (2004). Airflow Pattern and Temperature Distribution in a Typical Refrigerated Truck Configuration Loaded with Pallets. *International Journal of Refrigeration*, 27: 464–474.

[9]. Anonymyous., (2017). Testo 177H1 Datasheet, http://elcodis.com/parts/ 4018638/ 177H1.html# datasheet, access date: 18/12/2017)

[10]. Soysal, M. I. (2007). Principles of biometry (in Turkish). Trakya University, Tekirdağ Faculty of Agriculture Pub. no:95, Lecture notes no:64

[11]. Akdemir, S., and Arin, S. (2006). Spatial Variability of Ambient Temperature, Relative Humidity and Air Velocity in a Cold Store. *Journal of Central European Agriculture*, 7 (1): 101-110