Monitoring and Control of CA System for Food Storage

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ABSTRACT:

India is a vast country, where food & grain production is not uniform and there are highs and lows in the food production due to environmental condition. But due to problem of handling, transportation and insufficient facilities in storage houses leads to wastage of food and grain. This causes lot of revenue loss to the farmer and increase burden on public. Control Atmosphere Storage System (CA System) is one solution to avoid the above situations. The important parameters for maintaining good quality and increasing shelf life of food are temperature, relative humidity, ethylene, nitrogen and oxygen. CEERI has developed a PC based monitoring and control of the CA System. The developed CA System consists of an environmental chamber, sensor unit, controller unit, gas cylinders, regulators, flow devices, scrubbers and an Industrial PC. This system monitors all the necessary process parameters and maintains the set level for each fruit to be stored. The control of gases levels is taken care by scrubbing process (in case of gas level exceeds) or pumping gases into the CA System if the level is too low. The developed software has features like parameter display, data logging, online Graphs, Trends, History, Alarms, Remote Monitoring and Control (in a localized LAN). The system is installed and tested for apple and tomato for one month at CSIO Chandigarh. It is found that by controlling the storage parameters there is increase in shelf life of tomato by at least one week. Finally paper highlights development of smart embedded systems for determining the quality of food and grain storage houses.

Key words: CA System, shelf life, Lab VIEW

1. INTRODUCTION

Indian R&D contributed immensely in the field of food & grain through a series of innovative programs, which has resulted in self-sufficiency, higher yield, and better nutritional quality withstanding the ever growing population demand. Today we are finding especially in the area of food grains most of our godowns are reaching their storage limit (76%) [3]. Similar efforts have been made in the field of horticulture, floriculture, dairy and other products. In spite of our best efforts the yield of our crops are very low as compared to developed countries. Horticulture crops have high water contents and are thus subject to desiccation and mechanical injury, which leads to the growth of bacteria, fungus, and other microorganisms. For low shelf life food products, there more losses due to storage, packaging, handling, transportation and

demand supply. There is no connection between the low shelf life food products demand and supply. Also it is very difficult to predict the quality/shelf life of the product during the harvest stage. Due to these issues the estimated storage losses in the fruit and vegetable sector are around 25% [1]. The projected losses by 2020 in terms of rupees are around 5900/cr/yr. Our export potential is also affected by these issues. In order to overcome these issues there is a great need to develop appropriate technology suiting Indian environment. Govt. of India identified Controlled Atmosphere Technologies as one of the technologies to reduce these losses. The technology of Modified Atmosphere (MA) and Controlled Atmosphere (CA) are widely used for the storage, transport and packaging of several types of foods. CEERI along with CSIO has developed a CA System that can store the food products. The CA system monitors and controls the necessary process parameters, so that the food can be stored for longer duration without degrading its quality. The paper presents the details of the developed system along with the results. Also it discusses the present trends & important factors affecting the CA System.

2. PRESENT TRENDS AND IMPORTANT FACTORS

Modified Atmosphere (MA) and Controlled Atmosphere (CA) [4] are widely used techniques for storing of food products. The principle of Modified Atmosphere refers to any atmosphere that is different than the normal air (20-21% O_2, 0.03% Co_2, 78% N_2 and trace quantities of other gases). Once the gas mixture is introduced, no further control of the gas composition is exercised and the composition inevitably changes. So after changing the gas composition, the food items may be spoiled. Usually the modified and controlled atmospheres involve an atmosphere with reduced concentration of O_2 and an elevated concentration of Co_2. In order to maintain the food quality we should adopt the Controlled Atmosphere where the atmosphere composition is maintained and controlled throughout the storage time. Using this we can increase the shelf life food items, retarding of metabolic processes such as ripening in fruits and vegetables, retardation of the loss of some nutritional substances such as vitamins, decay control, insect control and control of some physiological disorders such as chilling injury in some fruits and vegetables [4]. The important parameters that are to be monitored and controlled in CA System [2] are temperature, relative humidity, ethylene, nitrogen and oxygen.

2.1 TEMPERATURE

Temperature measurement along with moisture content gives an indication for potential deterioration. Respiration and metabolic rates are directly related to room temperatures within a given range. Further it is observed that with higher the rate of respiration, the faster the produce deteriorates. Lower temperatures reduce respiration rates, the ripening and senescence processes, which prolong the storage life of fruits and vegetables. Low Temperatures also slow the growth of pathogenic fungi, which cause spoilage of fruits & vegetables in storage [2].

2.2 RELATIVE HUMIDITY

Relative Humidity: Relative humidity needs to be monitored and controlled in CA storage. Recommended RH is 85-90% for fruits, 90-95% for vegetables (except dry onions and garlic). The addition of water vapor to a cold storage chamber can be controlled automatically with a humidistat.

2.3 ETHYLENE

Ethylene: Ethylene, a natural hormone produced naturally by all plants and by some fruits as they ripen, promotes additional ripening. The damaged or diseased fruits produce high levels of ethylene and stimulate the other apples to ripen too quickly. As the fruits ripen, they become more susceptible to disease. Ethylene "producers" should not be stored with fruits, vegetables, or flowers that are sensitive to it. The result could be loss of quality, reduced shelf life and specific symptoms of injury. Ethylene producers include apples, apricots, avocados, ripening bananas, honeydew melons, papayas, peaches, pears, plums and tomatoes. Low temperature decreases production and action of ethylene. Ethylene scrubbers are used to remove excess Ethylene produced during storage.

2.4 NITROGEN

Nitrogen is a tasteless gas and is mostly used in Controlled Atmosphere as a filter gas because of its low solubility. Nitrogen is almost insoluble in water and fat, so it will not get absorbed into the food product. Nitrogen is used to displace oxygen from air. This will help in the case of oxygen sensitive products and as an alternative to vacuum to inhibit the growth of aerobic microorganisms.

2.5 OXYGEN

If Oxygen is permitted to go too low the produce becomes anaerobic; the tissue dies and begins to ferment thus causing permanent damage. Nitrogen is mostly used in Controlled Atmosphere to control O2 concentration in chamber

2.6 CARBON DIOXODE AND OXYGEN DAMAGE

CA storage have also adverse effects, at O_2 levels below 1%, in the absence of CO_2, anaerobic conditions can prevail with the consequent formation of alcohol and physiological changes. Also high CO_2 and low O_2 may cause abnormality in metabolism. The level of CO_2, which Scrubber: The unit consists of an activated carbon filter chamber, a low –pressure ventilator, an air-transport system, a control unit, and a buffer or lung system can cause damage to fruit and vegetables, varies between cultivars of the same crop. Variability in plant material prevents precise control of intercellular atmosphere; recommendations can be designed only to avoid complete anaerobic conditions and a harmful level of CO_2 in the centre of the permeable individual fruit and vegetable. Some examples of CA injury can be seen in Table 1[4]

Table 1: Examples of CA injury [4]

Crop and Cultivars	**CO_2 injury level**	**CO_2 injury symptoms**	**O_2 injury level**	**O_2 injury symptoms**
Apple, red delicious	>3%	Internal browning	<1%	Alcoholic taste
Apple, Fuji	>5%	CO_2 injury	<2%	Alcoholic taint
Apple, Gala Apricot	>1/5% >5%	CO_2 injury Loss of Flavor	>1.5% >5%	Ribbon scald Of-flavor
Banana	>7%	Green fruit softening	<1%	Brown skin, discoloration
Green beans	>7%	Off flavor	<55	Off-flavor
Cabbage	>10%	Discoloration of inner leaves	<25	Off-flavor
Cherry	>30%	Brown discoloration	<1%	Skin pitting, Off-flavor
Mango	>10%	Softening	<2%	Skin discoloration

3. SYSTEM DESCRIPTION:

Controlled atmosphere (CA) is a well-known technique and an important alternative to chemical preservatives and pesticides. CA is a Gas Control mechanism where levels of certain gasses in a closed chamber are maintained. In CA storage method, the levels of gasses such as O_2, Co_2, C_2H_4 along with Temperature and RH are continuously monitored and required % levels of O_2, Co_2 and C_2H_4 are maintained for a particular temperature and RH as per the requirement of storage fruit. It has a great potential for reducing post-harvest losses and for maintaining both nutritional and market value. Thus it will be worth to develop a system for monitoring and control of various parameters responsible for proper storing of fruits and vegetables. The range [2] for environmental factors in the closed chamber, which affect the quality of fruits & vegetables are:

Table 2: Range of Process Parameters

S.No	Process Parameters	Range
1	Ethylene (C_2H_4)	0-15 (ppm)
2	Carbon dioxide (CO_2)	1-25 %
3	Oxygen (O_2)	1-10%
4	Temperature	-2 to 18^oC
5	Relative Humidity	60 to 95%

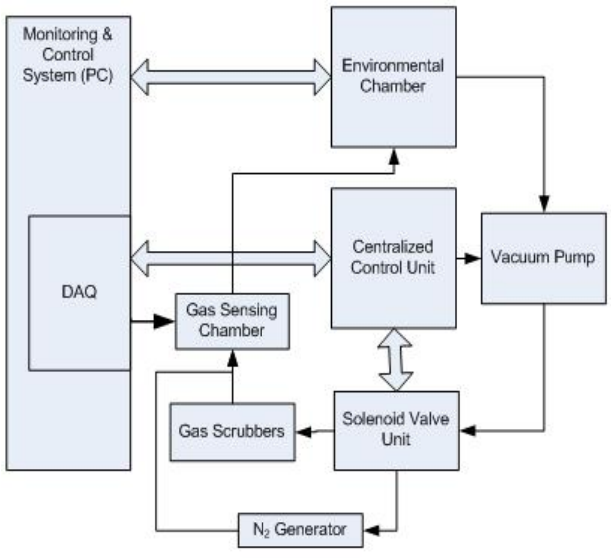


Fig 1: Block diagram of the CA System.

Fig 2: CA chamber along N_2 Generator

3.1 HARDWARE

We (CEERI) have developed, installed and tested a PC based monitoring and control for Control Atmosphere System at CSIO Chandigarh for fruits and vegetables storage applications. The block diagram of the developed CA System is shown in Fig1. The system consists of an environmental chamber, CO_2 scrubber for absorbing excess CO_2, Ethylene scrubber for absorbing excess Ethylene, N_2 generator for maintaining O_2 level, sampling chamber for sensing various gas parameters, auto/manual controller and a solenoid valve panel. Fig2 shows set up installed at CSIO, includes the environmental chamber along with centralized controller and N_2 generator. The solenoid valve unit consists of 6 valves out of which four valves are used to control the flow of N_2 pumping into the chamber for O_2, ethylene scrubbing, CO_2 Scrubbing. After passing through these sections, the gas will be passed through the gas sensing chamber and then it will be reentered into the environmental chamber. By default the gas will be directly flow through the gas sensing chamber. The air from the chamber is sucked through the vacuum pump. The flow rate of the system is measured using flow meters and the gas flow rate is controlled by using manual ball valves. The typical flow rate of the gas that is coming out of the chamber is set at 5-20 $lmin^{-1}$. Similarly the flow rate of the N_2 gas coming out of the reservoir is set between 10-30 $lmin^{-1}$. Purging is a must before starting of the process as well as at the end of the process i.e., before opening of door. If purging is not carried before opening the door, the concentration of gases inside the chamber may be hazardous to the operator. Necessary precautions are taken like warning messages pasted on the chamber to avoid these situations.

In the environmental chamber, four temperature sensors are placed at different locations. Each individual temperature as well as the average temperature of the chamber is displayed on the chamber control box. Average temperature is used for taking necessary action. The RH sensor measured using psychometric principle is placed in the middle of the environmental chamber. The sensing of gases, temperature, RH etc through ADC module of the DAQ card and control of solenoid valve is done using the digital I/O ports of the DAQ card. Advantech PCL-818HG multipurpose DAQ card is used for fulfillment of the above requirement. The environmental chamber control unit is controlled using RS-232 communication. Isolation mechanism is provided between the solenoid valves and the DAQ card in order to protect the DAQ card from spikes, surges

due to difference in voltage between input and output. The gas sensors along with transmitter are connected to the analog channels of the DAQ card.

3.2 SOFTWARE

The monitoring and control algorithms of the CA System is developed using Lab VIEW software platform. The developed software have features like auto and manual control of the process, data logging, setting alarms limits, alarms logging, visual alarms, gas flow path, trend graphs, history graph, histogram, control settings etc., The GUI of the developed software is as shown in Fig 3.

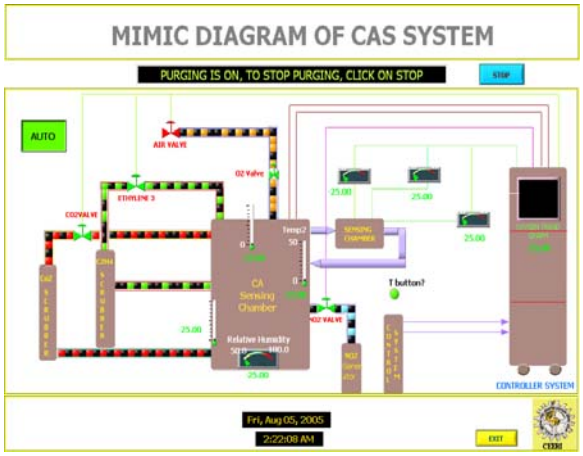


Fig 3: Mimic diagram of the CA System

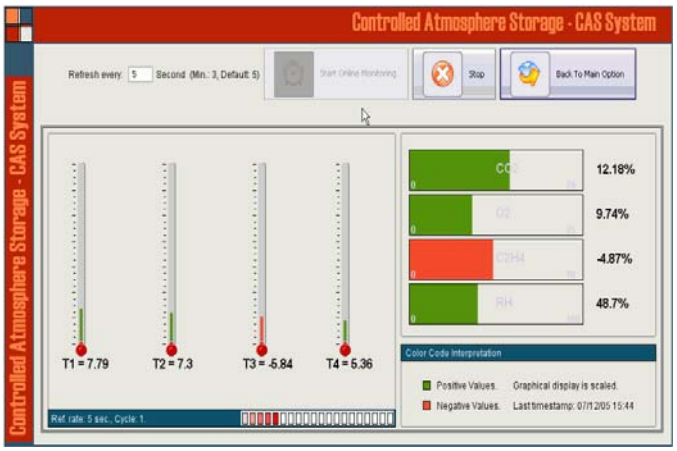


Fig 4: CA System on CSIO Intranet

Auto/Manual control for the process is provided so that the user can carry out necessary initial experiments. Once these experiments gave desired (parameter settings for fruit under storage) results, they will be configured into auto process. The successful configuration along with the fruit details will be saved into the database. Oracle database is used to store all the necessary and important information. All control logics are stored in date wise format for particular fruit/vegetable under storage. Measured process parameters are stored in a table. Alarms are stored separately with remarks and error code. User can view the history graph based on date and time wise. The data from the database can be exported into other formats like excel and text for further processing.

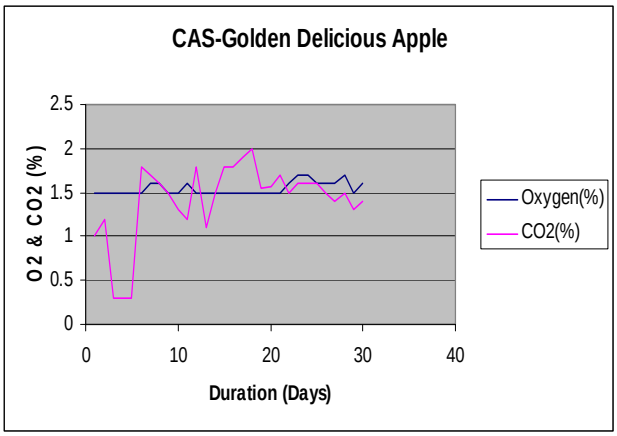
Further, Java based web application is developed for monitoring the multiple CA System online. In this application, the user can only monitor the process parameters and the trend graph & history of the selected CA system as shown in Fig 5. Manipulation and access of data or control actions are prohibited in the online

application due to safety and security reasons. The data on central computer will be updated for every 5 mins, user can change the update rate from (3 min to 1Hr). The developed application software is successfully tested at CSIO Chandigarh using local LAN.

Fig 5: Trend & History Graph

4. RESULTS AND CONCLUSION:

Golden delicious Apple was purchased locally from Chandigarh market. The apple about 50 Kg was kept in environmental chamber and tested for 6 - 8 months, from the results, it was observed that the O_2 and CO_2 levels varied < 1% during the test cycle. The dip in the sensor reading was due to failure of the gas sensing chamber electronics due to the main power supply failure. For initial period of 3-4 days the CA System was controlled manually and appropriate setting of all control parameter have been done in order to get proper shelf life of the stored apples During the testing of the sample in the CA System, simultaneously offline laboratory testing and measurement of randomly selected stored apple samples for determining and comparing its quality was carried out by the CSIO team; the results of these experiments parameter variations are shown in Fig 6 & Fig 7. It was observed only firmness of the apple changed during the storage period. Later, tomatoes also kept in the CA System and tested for 6-8 weeks. The test samples are not uniform in terms of their life, few samples are in the maturity stage 2 and few are in the maturity stage 3. Due to this the desired results can't be attained. It is necessary to store uniform samples and so that the control logic can be implemented effectively. The results are then compared with the results of CFTRI CA System [6] and they are tabulated in Table 3.



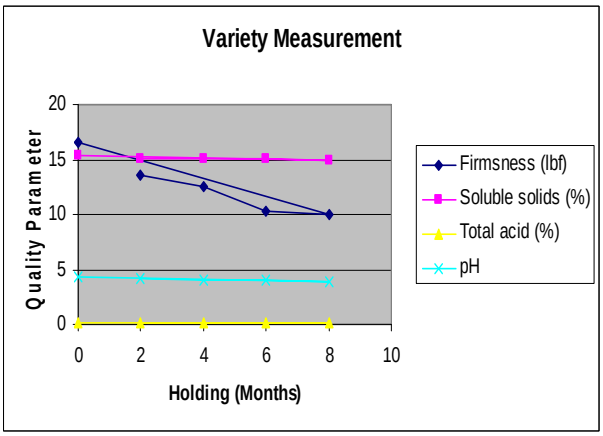


Fig 6: Variation of O_2 and CO_2

Fig 7: Variation of O_2 and CO_2

Table 3: Test Results

Type	Temperature		Duration	
	CEERI	CFTRI	CEERI	CFTRI
Apple	0 to 2°C	1°C	7-8 months	10 Months
Tomato	9 to 14°C	10 to 12°C	6-8 Weeks	10 Weeks

Due to the rapid development in the area of smart sensors/electronics, presently CEERI is working on the development of embedded ARM based controllers, having latest features of touch screen display, wireless connectivity, email connectivity, mobile network etc. the developed system will be low cost, miniature in size and easy to install and operate.

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