# CONTRIBUTION TO PERFECTING TEMPERATURE AUTOMATIC ADJUSTMENT SYSTEMS IN VEGETABLES AND FRUITS WAREHOUSES

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***Abstract**: The researches object in this paper consists in the realization of an improved system of automatic adjustment for temperature in warehouses for vegetables and fruits, which have simultaneous high safety in operation and reliability . The research stage. Vegetables and fruits presents a major importance for people nutrition, their contribution in different nutrition substances and vitamins being essential in humans health. Consuming them immediately after harvesting is possible on short periods of time, in most cases being necessary their storage. In the paper is researched only the problems of fruits and vegetables storage in a fresh condition , depositing which is made on short periods of time (green papers - 8…10 days, strawberries- 1…5 days, cultivated mushrooms-3…7 days etc.), average periods of time (watermelons-2 weeks, carrots in links-2 weeks, early potatoes-2…3 weeks) or long periods of time (late potatoes for consume-4…8 months, Ionathan apples -4…8 months, grapes-3…5 months), depending on the variety and products destination. For the most important fruits and vegetables produced in Romanian are specified the temperature, humidity and atmospheric characteristics intervals, which can assure the storage on a précised period of time with minimum depreciation on the biological and nutritive characteristics of this products. For assuring this conditions, in this case of temperature limits, is necessary the using of proper storage rooms, but also the use of automatic adjustment of temperature, as performing as possible. After a comparative analysis of this installations performances, it is concluded that is necessary and possible their perfection, both in functional performances and high safety in operation and reliability. Method and materials used. From the individual parts analysis of the temperature automatic adjustment schemes used in warehouses for fruits and vegetables storage, in the paper is proposed a variant for replacing them, which includes the latest global developments included in the scheme. This scheme gives superior means of monitoring the frequency adjustment and the defects apparition, requiring human intervention. For the scheme parts of the automatic temperature adjustment is made a research for the predictable reliability of the similarly components used in current equipments. The originality and the importance of the paper. From the technical-economical comparison of the actual system and proposed system for automatic temperature adjustment in warehouses for vegetables and fruits storage, results that the proposed system is in all aspects more performing .Using the automatic adjustment system for temperature adequately for fruits and vegetables variety and the storage types will permit their efficiency, knowing that in Romania will be build an important number of this kind of warehouses.*

***Key words***: *vegetable and fruits, warehouse, temperature, automatic adjustment.*

## INTRODUCTION

Vegetables and fruits are having a great importance in human alimentation. By their high water content are participating to organism rehydration. The sugar in fruits and vegetables suffers an oxidation process from which results the necessary energy to organism vital activities. Organic acids are contributing to increasing the appetite, combating body fatigue, having a bactericidal action etc. Mineral substances, by their different nature, help to skeletal ossification, contributes to restoration of blood hemoglobin, influences growing, some glands with internal secretion activities etc. Cellulose, peptic substances and tanoid substances are having a laxative action. By their action, vitamins are contributing to human organism normal operation, is helping his growth and development. Also, flavors are giving the fruits and vegetables pleasant teas, are stimulating gastric and intestine secretion, are increasing the appetite etc. [BANU, A.C. AND COLL.].

In general, fruits and vegetables that are eaten exercise an alkaline biological action in human organism. Organic acids and their salt are metabolized, resulting $CO_2$ and $H_2O$, and the bases that remains under carbonates form are increasing the organism alkaline reserve

Fresh fruits and vegetables consumption, immediately after harvesting, is limited by their relatively short time of perishable, reasons for which are necessary conservation methods that can enable nutritive characteristic preservation for long periods, eventual throw whole year duration. That is way are necessary refrigeration and freezing methods and also adequate warehouses, in which the environment conditions are strict respected. The most important storage condition in vegetables and fruits warehouses is the ambient temperature. This must be assured in limits that are specific for stored products variety. Any accidental deviation can compromise those products characteristic.

Choosing the refrigeration and freezing method depends by products perishable degree, those with high perish degree must be cooled very quickly. From the perishable degree point of view, fruits and vegetables are divided in the following groups:

- extremely perishable products: blueberries, strawberries, blackberries raspberries, mulberries, fresh figs, spinach, sorrel, cress;
- very perishable products: apricots, cherries, quinces, early apples, early pears, peaches, plums, grapes with soft skin, green onions, mushrooms, Cornichon cucumbers, green beans, peas green beans, carrots with celery, parsley leaves, early leeks , lettuce, asparagus beetroot, green celery, green garlic, early cabbage;
- perishable products: summer pears, grapes, olives, artichokes, peppers, Okra, beans, cauliflower, green beans, peas, carrots, cantaloupe, tomatoes, cabbage, Brussels sprouts, eggplant, leeks;
- relatively resistant: autumn apples, winter pears, chestnuts, potatoes, onions, horseradish, parsnip roots, beetroot, garlic head.

Horticulture (fruits, vegetables) products storage is made in frigorific spaces with normal or modified atmosphere, the storage conditions being presented in table 1.

## MATERIAL AND METHODS

The main factor of maintaining fruits and vegetables fresh is represented by natural active immunity, respectively the specific metabolism for each variety. An important role is had by the passive immunity, determined by the specifically epicarp characteristics, the structural-textural characteristics and by maturation degree.

The storage temperature is a factor that determines the chemical and biochemical reaction speed, also the water evaporation speed, which inhibits microorganism's development. There are known the following temperature levels:

- the optimum storage temperature;
- critically temperature, over their limits physiological disturbances are produced;
- lethal temperature, which provokes the tissue death.

Setting the storage temperature must be done, so the aerobe breathing is reduced to minimum, responsible for consuming the reserve substances, without the anaerobe breathing to appear, which affects the metabolism. Is very important keeping this temperature to a constant level.

For the realization of optimum storage condition for vegetables and fruits in warehouses is necessary the control and the automatic adjustment for the environment parameters, respecting the following conditions:

*Table 1*

Parameters for fruits and vegetables storage in refrigeration condition

| Product | Storage temperature , °C | Air relative humidity , % | Maximum storage time |
|---|---|---|---|
| Blueberries | 0...1 | 90...95 | 2...3 months |
| Gooseberries | -1...0 | 85...90 | 1...4 weeks |
| Artichokes | -0,5...0 | 85...90 | 1...3 weeks |
| Green peppers | 7...10 | 85...90 | 8...10 days |
| Chili pepper | 0 | 85...90 | 4...5 weeks |
| Broccoli | 0 | 90...95 | 10...21 days |
| Apricots | -1...0 | 70 | 2...4 weeks |
| Early potatoes | 3...4 | 85...90 | 2...3 weeks |
| Late potato to consume | 4,5...10 | 88...93 | 4...8 months |
| Late seed potato | 2...7 | 85...90 | 5...8 months |
| Cucumbers | 11,5 | 85...90 | 2 weeks |
| Strawberries | 0 | - | 1...5 days |
| Onions | -3...0 | 70...75 | 6 months |
| Chicory | 0...1 | 90...95 | 2...3 weeks |
| Cherries | -1...0 | 85...90 | 1...4 weeks |
| Cultivated mushrooms | 0...1 | 85...90 | 3...7 days |
| Cauliflower | 0...1 | 85...90 | 3...6 weeks |
| Courgettes | 10...13 | 70...75 | 4...6 months |
| Green beans | 2...7 | 85...90 | 10...15 days |
| Quinces | 0...4 | 90 | 2...3 months |
| Kohlrabi | 0 | 90...95 | 2...3 weeks |
| Horseradish | -1...0 | 90...95 | 10...12 months |
| Peas | -0,5...0 | 85...90 | 1...3 weeks |
| Ionathan apples | 2...3 | 85...90 | 4...8 months |
| Golden apples | 1...2 | 85...90 | 5...6 months |
| Conference pears | 0...1 | 85...90 | 3...6 months |
| Carrots in links | 0...1 | 90 | 2 weeks |
| Carrots without leaves | -1...1 | 90...95 | 4...6 months |
| Green walnut | 7 | 70 | 1 year |
| Melons | 0...1 | 85...90 | 7 weeks |
| Watermelons | -1...1 | 85...90 | 2 weeks |
| Parsnips | -0,5...1 | 90...95 | 2...6 months |
| Parsley | 0...1 | 85...90 | 1...2 months |
| Peaches | -1...1 | 85...90 | 1...4 weeks |
| Leek | -0,5...1 | 90...95 | 1...3 months |
| Plums | -0,5...1 | 85...90 | 2...8 weeks |
| Lettuce | 0...1 | 90...95 | 1...3 weeks |
| Edible sugar | 0 | 90...95 | 1...3 months |
| Autumn Spinach | -0,5...0 | 90...95 | 1...2 weeks |
| Grapes | -1...0 | 85...90 | 3...5 months |
| Ripened tomatoes | 0 | 85...90 | 1...2 weeks |
| Ripe tomatoes | 11,5...13 | 85...90 | 3...5 weeks |
| Celery | 0...1 | 90...95 | 0,5...2 months |
| Garlic | -1,5...0 | 70...75 | 6...8 months |
| Cabbage | 0 | 85...90 | 2...6 months |
| Brussels sprouts | -1...1 | 90...95 | 2...6 weeks |
| Eggplant | 7...10 | 85...90 | 10 days |
| Raspberries | 0 | 85...90 | 3...5 days |

- the temperature, relative humidity and $CO_2$ content must be kept approximately constant in different storage time;
- the correlation of the storage regime with temperature and humidity values from the external warehouse air (which depends by the concrete climatic conditions ) and with the

physical situation of the vegetables crop (degree of maturation, amount of impurities, layer height of stored products etc. )[ BURLEA, O.R.].

These conditions can be respected only by introducing automatic systems for ventilation and temperature and humidity adjustment, namely by parametric automation adjustment for air conditioning. Installations used in this propose can be realized in many constructive variants. The scheme for a simple air conditioning installation that can be used in a warehouse for vegetables and fruits storage is presented in figure 1. This is provided with sensors for temperature measurement and adjustment (6 and 7 thermostats). Connecting these thermostats to the comparison element 8 and adjustment 9, permits shutter control 3 and 4, this provides air aces inside the warehouse. The others notations in figure 1 are having the following significations: 1- stored product, 2- ventilation stack, 5-venilator.

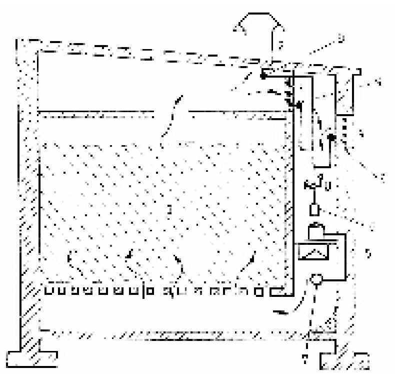

*Figure 1. General scheme of a automation installation for fruits and vegetables warehouses*

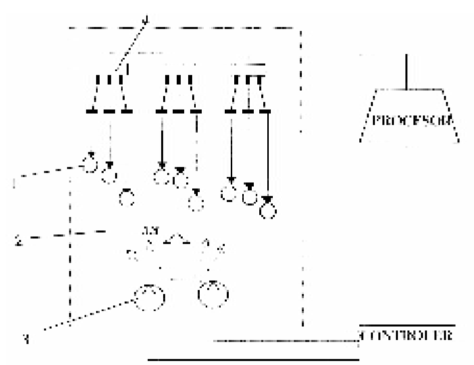


*Figure 2. Controlling and monitoring the temperature in a large capacity warehouse*

There are multiple ways for temperature controlling in a warehouse, as it results from the proposed scheme in figure 2. So, in a central date acquisition point it can be collected information from 1000 temperature sensors 1, placed in a distance of maximum 100 m. In large capacity warehouses in can be used temperature sensors mounted in a plastic capsule, placed between products, connected so it can give the medium temperature along their height. The others notations from figure 2 are having the following signification: 2- storage cellule; 3- ventilators; 4- junctions boxes. This kind of sensors are having the disadvantage that they are not giving the points where appears disorders caused by microorganisms development, which can be observed by temperature differences. To eliminate this disadvantage in can be used individual cabled sensors, placed to précised distances. Information from sensor is sent to a controller which stocks and displays the collected data. For reducing the cable installation costs, necessary to temperature sensors it can be done the star cabling. So it's used a single multicolor cable which takes information from 100 sensors and then transmitting them to the junction box, placed inside the warehouse. From this point there are placed others junction boxes, outside the warehouse, serial connected with the help of multicolor cables. Information form each probe is transmitted to the nearest junction box for the network easy assembling [CEPISCA,C.].

Each sensor contains an electronic controller which offers the possibility that the exit can be isolated from the measurement instrument or placed to a display, using a three spinning cable. The 100 tree spinning connections are coupled to a multicolor cable in a decimal matrix, by which the operator can address to only one sensor, using the rotated decimal switch. This form of selection makes possible reading to a single measurement instrument, information from 1000 sensors, through a serial connection. The sensorial circuit used in this system creates an electrical current proportional with the temperature, which eliminates possible errors caused by cables and switch resistance from the circuit. [BRATUCU.GH. AND COLL.]

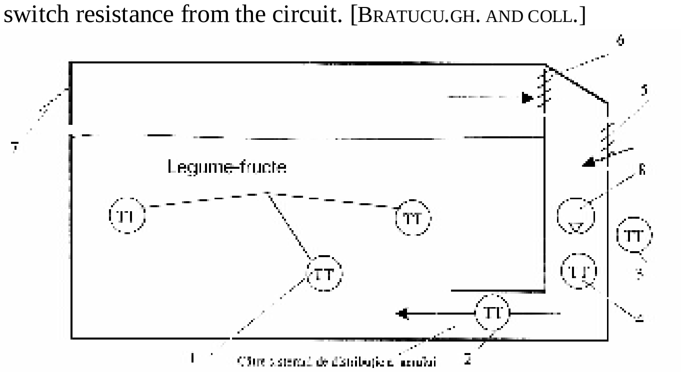


Figure 3. Controlling and monitoring the temperature in a warehouse for fruits and vegetables

In figure 3 is presented the scheme for a fruits and vegetable warehouse, in which the products can be maintained to a temperature which varies between $\pm 2{,}5\ ^{o}C$ limits, according to their destination. The scheme is provided with temperature sensors 1 and safety thermostats 2 for the whole system and interior blinds 6 and exterior blinds 5, which assures the air recirculation, but also introducing air from outside. In normal activities the inside air is recycled by the ventilators 8 and with the reversible electrical engines, until a sufficient outside air quantity is introduced in the warehouse for assuring the optimum inside temperature. The others notations in figure 3 are having the following significations: 3- outside temperature transducer; 4- temperature transducer for the air inside the main canal; 7- safety blinds.

If the temperature inside conductors is with $2{,}5\ ^{o}C$ under the fixed temperature, the blending unit is commanding the ventilators stopping and the blinds closing . When this situation is happening or when the outside blinds are closed because the external temperature is to high, the blending unit is programmed to return to the initial situation after 1…8 hours.

Leds indicates the moments in which the air is having optimum temperatures, when the blinds are closed or open and when the ventilators are closed. For having a precise control of the situation inside the warehouse it can be mounted humidity and temperature sensors to the base and top of the vegetables or fruits stored.

## RESULTS AND DISCUSSIONS

A problem of great importance for assuring optimal conditions for storing vegetables and fruits in warehouses is represented by the good function control and climate adjustment. Under this aspect is important to be compared different equipments which meet this role and based on their predictable reliability, and if there are sufficient data for some of the components the operational reliability will be studied, offering the possibility to planned interventions for replacing weak components.

For the schemes presented in figures 1,2 and 3 the systems main components for adjusting and controlling the climatic parameters from warehouses are : temperature and humidity transducers, digital thermostat, ventilators, buttons, electrical reversible engines, comparators, electrical valves, magnetic relay, digital timer, socket element, contact piece etc.

For choosing systems like this it must be taken into account also an essentially economic criterion, respective the reliability-price criteria. In this phase it can be done a study regarding the predictable reliability, as it is presented forward.

The predictable reliability is calculated by adopting particular values for the failure intensity of the elements which was determined experimentally. In specialized literature the medium values of the failure rate are being presented. In table 2 these values are shown [BRATUCU.GH] .

Using the exponential repartition low by witch z(t)=λ=const, the element reliability is being calculated by relation 1:

$$R(t) = e^{-\lambda t} , \qquad (1)$$

where :R(t) is reliability function; $\lambda$ - constant failure rate; t-reference(calculation) time.

In table 3 is being presented the reliability function R(t) estimation for its elements using time interval T(i). Failure intervals ΔT are being determined using relation 2:

$$\Delta T = \frac{T_{\max} - T_{\min}}{1 + 3{,}3 * \lg \sum N_i} , \qquad (2)$$

*Table 2*

Medium values of the failure rate

| Component elements | Failure rate , $\lambda * 10^{-6}/h$ |
|---|---|
| 1. Button | 0,069 |
| 2. Electrical valve | 0,18 |
| 3.Temperature transducer | 1,3 |
| 4.Humidity transducer | 1,3 |
| 5. Digital thermostat | 0,3 |
| 6. Digital timer | 1,2 |
| 7.Electrical reversible engine | 6,8 |
| 8. Contact piece | 2,5 |
| 9. Socket element | 7,26 |
| 10. Magnetic relay | 0,25 |
| 11.Comparator | 1,65 |
| 12.Ventilator | 7,5 |

where: Tmax and Tmin represents manifestation times for the last and firs failure for a piece, in hours, and Ni the recorded failure number. From calculations Tmax= 10 000 h, Tmin=500 h, Ni=20 and ΔT=1800 h. In table 3 numbers form 1 to 12 represents the automation equipment pieces specified in table 2.

*Table 3*

Predictable reliability function R(t) values

| *No/ΔT(i)* | 900 | 2700 | 4500 | 6300 | 8100 | 9900 |
|---|---|---|---|---|---|---|
| R(Ti) for the component elements | | | | | | |
| 1. | 0,9999 | 0,9998 | 0,9996 | 0,9995 | 0,9994 | 0,9993 |
| 2. | 0,9998 | 0,9995 | 0,9991 | 0,9988 | 0,9985 | 0,9982 |
| 3. | 0,9988 | 0,9964 | 0,9941 | 0,9918 | 0,9895 | 0,9872 |
| 4. | 0,9988 | 0,9964 | 0,9941 | 0,9918 | 0,9895 | 0,9872 |
| 5. | 0,9997 | 0,9991 | 0,9986 | 0,9981 | 0,9975 | 0,9970 |
| 6. | 0,9989 | 0,9967 | 0,9946 | 0,9924 | 0,9903 | 0,9881 |
| 7. | 0,9938 | 0,9818 | 0,9698 | 0,9580 | 0,9464 | 0,9348 |
| 8. | 0,9977 | 0,9932 | 0,9888 | 0,9843 | 0,9799 | 0,9755 |
| 9. | 0,9934 | 0,9805 | 0,9678 | 0,9552 | 0,9428 | 0,9306 |
| 10. | 0,9997 | 0,9993 | 0,9988 | 0,9984 | 0,9979 | 0,9975 |
| 11. | 0,9985 | 0,9955 | 0,9926 | 0,9896 | 0,9867 | 0,9837 |
| 12. | 0,9932 | 0,9799 | 0,9668 | 0,9538 | 0,9410 | 0,9284 |
| R(Ti) total | 0,9725 | 0,9207 | 0,8719 | 0,8256 | 0,7818 | 0,7403 |

CONCLUSIONS

- Storing vegetables and fruits in warehouses requires precise conditions for temperature, humidity and $CO_2$ content. For this reason are necessary complex systems for adjustment, control and monitoring of these parameters, conforming to specific requirements for stored vegetables and fruits variety.
- The permanent control and monitoring of how the adjustment systems for the climatic factors in vegetables and fruits warehouses respects the optimal values lead to making more performing equipments under functional and reliability aspect.
- For choosing and implementing an automatic adjustment system for the climatic factors in vegetables and fruits warehouses is necessary a study of type reliability-price. In this paper is offered a model for computing the predictable reliability of the proposed automatic systems

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