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ASPECTS OF THE USE OF OZONE IN FRUIT PROCESSING TECHNOLOGY

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Abstract: In response to increased consumer demand for healthful food products, finding sustainable and eco–friendly technologies became a true challenge. Based on the latest regulations of the relevant authorities, the ozone treatment into the sector of horticultural products capitalization and food industry was unanimously recognized as wholly safe for humans. Due to ozone property to be converted into oxygen by autolysis, it is used in the ecological technologies as disinfectant, antimicrobial and pesticides residues remover in the contact food applications. The study aims to demonstrate the ozone efficiency in apple juice processing line at ICDIMPH – Horting and to exhibit the prototype of ozone preparation in aqueous solution.
Keywords: apple, juice, ozone, equipment

INTRODUCTION

The food industry targets to develop innovative technologies to launch healthy, natural and sanogenous products, richer in nutrients and higher in sensory characteristics, in order to fulfil consumer's expectation. In accordance with the standards and good agricultural practice, new technologies in the field of horticultural crops protection & capitalization are currently being implemented, which, however, are struggling to remove the pesticide active compounds residues. Pesticide residues are long–lasting and are slowly reduced in plant tissues (Nowacka, 2009). Residue levels of benomyl, carbendazim, methyl thiophanate and thiabendazole in apples stored at 0–2° C were found even after 140–150 days when the active ingredients have reached a level of 36–60% from their initial concentration (Holland, 1994).

To reduce impurities, washing the fruits with certain detergents is commonly used. Such methods are able to remove pesticide residues that are transferred to the washing solution.

Washing efficiency depends on several factors, such as the place of the residue on fruit surface, elapsed time since exposure to the active ingredient and water solubility to a particular residue. The temperature and washing type have an impact on this process, as well. The use of additional detergents or cleaning agents and the temperature of washing solution can considerably influence the efficiency of the process (Holland,1994). This way, the active compounds of pesticide are released into the water, air and soil (Tiwari B.K.2009), empoisoning the environment. The side effects of such method is a weapon turned against life & wellness, in all its dimensions.

Technologies using ozone have expanded in the recent years, due to the fact that it promotes disinfection, virus inactivation, deodorization, bleaching (decolorization), decomposition of organic matter, degradation of mycotoxins and others (Balawejder M., 2013). Ozone (O3) is a natural gas in the atmosphere, one of the most powerful antimicrobial products that acts against a wide range of microorganisms. Ozone is an allotropic form of oxygen that is a strong oxidant (E0 = 2.07 V) which allows the oxidation of many organic compounds.

Fruits and vegetables are usually/ commonly sprayed with aqueous ozone solution or passed through into such solution in the processing line. The use of the ozone solution is possible due to its solubility in water, which is about 0.105 g in 100 cm3 at 0º C. If ozone is applied in aqueous solution, contaminants oxidation is based on direct oxidation of ozone molecules or indirect free radicals' oxidation. Catalytic oxidation of ozone leads to the generation of very strong oxidants (E0 = 2.8 V) and hydroxyl radicals (•OH). The hydroxyl group produces radical reactions with organic compounds of hydrogen extraction or electrophilic dependence on double bonds (Chiron S., 2000).

A wide range of pesticides are used in the treatments of agricultural crops. Ensuring an efficient washing of fruits and vegetables to remove the pesticide active compounds' residues, is done by meeting the following requirements:

≡ the generation source of ozone is the atmospheric air;
≡ the achievement of an optimal O3 concentration in the washing water;
≡ the flow adaptation of the ozonated solution to the working capacity of the washing equipment.

MATERIALS AND METHODS

In order to implement the ozone treatment to the horticultural products, the scientists of ICDIMPH–Horting and INMA Institutes have developed a practical equipment. The engineers have shared their ideas and they succeeded to create a new vision of technology. The concept and the prototype of ozone preparation equipment represents a bridge of their practical knowledge and joint efforts in the field. The washing phase of the raw material (apples) from the current technology used at Horting Institute to obtain apple juice, has been adapted / transformed so that the washing is done with ozonated solution. The scheme of the technological plant is shown in Figure 1.

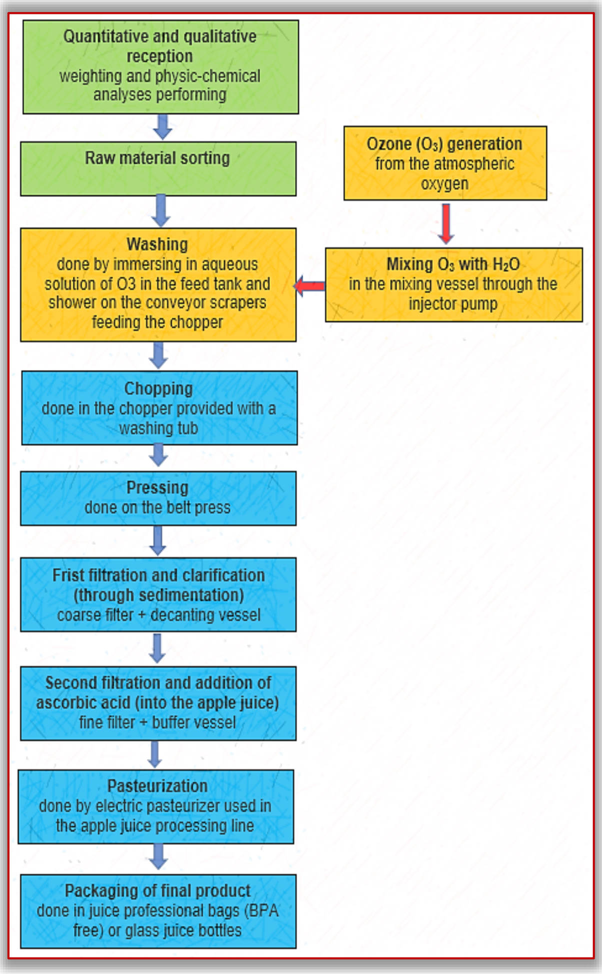

Figure 1 – Technological scheme of ozone plant applied at ICDIMPH – Horting

Starting from the main scheme of ozone solution preparation, presented in figure 2, the research team has realized the equipment's design of ozone preparation in aqueous solution – EOP (Figure 3).

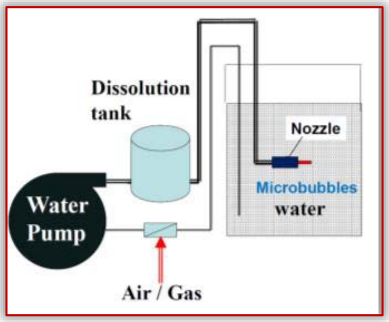

Figure 2 – Obtaining the ozone solution (Janyawat T. Vuthijumnonk and Warawaran Shimbhanao. 2019)

The EPO installation represents a prototype of an experimental model of a plant able to produce and distribute the ozonated water solution required for the washing plant existing to the apple / tomato juice production lines at ICDIMPH–Horting within the Experimental Base for the Processing of the Horticultural Products.

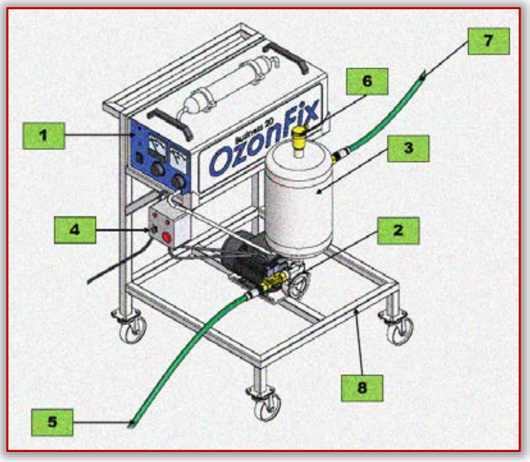

Figure 3 – General drawing of ozone preparation equipment (EPO)
1 – ozone generator; 2– drive motor + injector pump; 3 – mixing vessel; 4 – control panel; 5 – water supply connection; 6 – safety valve; 7 – ozonated water distribution connection; 8 – fitting frame

The aqueous ozone solution equipment (EPO) is supplied with water through the connection no. 5, directly from the drinking water supply network of the working point or from a buffer tank. The injector pump driven by an electric motor (2) takes up the ozone gas supplied by the generator (1) by means of the special connection intended for this purpose and disperses it in the volume of water circulated in the pump, from the inlet to the discharge.

The main elements of the aqueous ozone preparation (EPO) equipment are: (i) ozone generator; (ii) injector pump; (iii) pump drive motor; (iv) mixing vessel; (v) fitting frame.

The ozone generator (Figure 4) is a technical equipment designed to produce the gaseous ozone through the effect of "Corona" – type electric discharge with atmospheric air supply. The generator has an ozone gas production of up to 20 g / h and a lifespan of up to 20,000 hours of operation.

The injector pump (Figure 5) is the element that converts the mechanical power supplied by the motor drive into hydraulic power, while aspirating and dispersing the ozone gas from the ozone generator, through the "Venturi" type injector whose components parts are in the water.

The pump drive motor (Figure 6) represents the source of mechanical power required to operate the injector pump, for the purpose of dispersing gas ozone in water and transferring it to the additional mixing vessel, for better homogenization and supply of ozone in aqueous solution to the distribution system on the external surfaces of /, used to clean and treat the horticultural products.

Figure 4 – Ozone generator

Figure 5 – Injector pump

Figure 6 – Pump drive motor

Figure 7 – Pump drive motor

The mixing vessel (Figure 7) is a stainless steel vessel, provided as an additional means of homogenizing the gas–water mixture. It is made of a cylindrical ferrule and two semi–ellipsoidal bottoms. A fitting is provided at the top to fit an automatic valve breather required for the discharge of excess ozone gas if it would accumulate above the liquid ozone gas and water mixture.

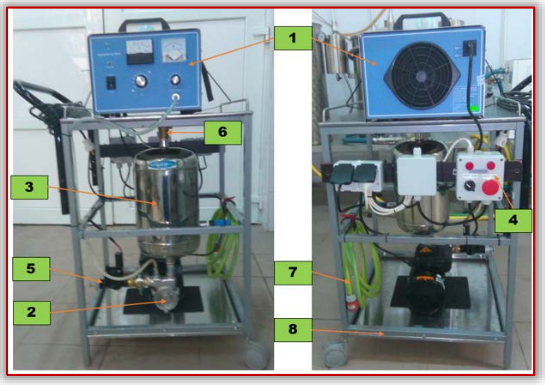

Figure 8 – Pump drive motor
1– Ozone generator; 2– Injector pump; 3– Mixing vessel; 4– Control panel; 5– Water supply connection; 6– Safety valve; 7– Ozonated water distribution connection; 8– Fitting frame

A fitting is provided at the bottom for the inlet of the ozone gas–water mixture from the injector pump. An additional homogenized exhaust connection to the ozone gas–water mixture distribution system is provided on the surface of the cylindrical ferrule.

The experimental model / prototype of the Ozone Preparation Equipment (EPO) in aqueous solution made at INMA – Bucharest is presented in Figure 8.

The ozone preparation equipment (OPE) in aqueous solution was installed on a wheeled transport frame, which allows it to be moved for coupling to the washing systems of the processing lines.

The fruit experiments aimed to test—the equipment's functionality in real production conditions.

Jonagored (derived from *Jonagold*) and *Florina* apple varieties provided by the Research–Development Station for Fruit Trees Cultivation (SCDP) – Baneasa were used in the experience. The phyto–sanitary protection of the apple species consisted in the application of four treatments during the vegetation period and one during the rest period, as follows:

1. Vegetative rest stage (December–February): treatment with *Bordeaux mixture*, in concentration of 3–5%, applied to reduce the spores' population of the most aggressive pathogenic fungi, such as, *Venturia sp*., *Erwinia sp*., *Podosphaera sp., etc.*
2. Bud break – "mouse ear" stage (March–April): treatment with Bordeaux *mixture*, in concentration of 0,5%;
3. End of flowering – 75% of petals are fallen (April–May): treatment with *Folicur* solo *250*, in concentration of 0,04% and *Vantex*, in concentration of 0,01%;
4. Fruit growing stage (May–June): treatment with *Score 25 EC*, in concentration of 0,02%, *Karate zeon*, in concentration of 0,02% and Fertitell, in concentration of 0,5%;
5. Fruit ripening (July–August): treatment with *Captan*, in concentration of 0,2%, *Karate zeon*, in concentration of 0,02% and Fertitell, in concentration of 0,5%.

The phyto–sanitary treatments carried out during the vegetation (Figure 9) rest period aimed to protect trees against the attack of the main pathogens (*Venturia sp., Erwinia sp., Podosphaera sp.*) and pests (*Eriosoma sp., Aphis sp., Cydia sp., Quadraspidiotus sp.*).

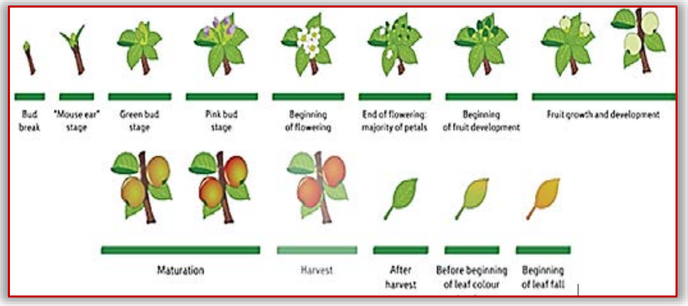

Figure 9 – The state of vegetation in the apple
(https://intermag.eu/crop–farming/crop–guides/)

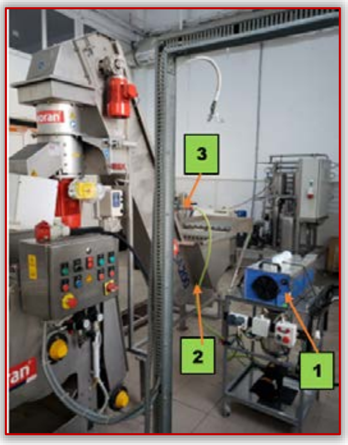

Figure 10 – Coupling the OPE to the processing line: 1–ozone preparation equipment; 2–supply hose for aqueous ozone solution; 3–washing ramp with showers

The way to connect the installation to the shower wash ramp is shown in figure 10.

During the experiments, the apples were washed by showering (Figure 11) and by immersion (Figure12), within the processing installation for natural apple juice, existing in the endowment of Horting Institute.

Figure 11 – Washing with showers

Figure 12 – Immersion wash

CONCLUSIONS

Following the experiments performed, the following aspects resulted:

≡ when the aqueous ozone tank is fed from the tank, due to the fact that the pump discharge circuit remains under pressure due to the pressure exerted by the weight of the volume of liquid remaining in the mixing vessel and the drain hose, and the pump inlet circuit is blocked by the flow valve, the liquid is forced out of the pump through the ozone inlet connection. This increases the pressure and the level of the liquid in the ozone supply hose and increases the risk of the hose breaking or the failure of the special one–way valve for ozone–gas circuits. In this context, it is recommended to install a one–way valve immediately after the pump discharge connection, so that when the system is switched off, the liquid remaining on the discharge does not enter the pump;

≡ in the case of the evacuation of the aqueous ozone solution to the nozzle ramp of the fruit washing machine, the problem previously identified and presented, became even more pronounced. This problem is due to the fact that the pump discharge circuit remains under pressure due to the pressure accumulated on the section from the nozzle ramp, and the pump inlet circuit is blocked by the direction valve, the liquid being forced out of the pump through the connection ozone inlet increasing pressure and fluid level in the ozone supply hose. As a result, the previous recommendation regarding the installation of a one–way valve immediately after the pump discharge connection is all the more stringent.

The parameters and factors that influence the effectiveness of ozone treatment are: (i) water quality (pH, organic matter, pressure and temperature); (ii) air quality (relative humidity); (iii) the treatment itself (method of application, duration of treatment and concentration); (iv) horticultural product characteristics (cultivar, weight, product surface characteristics); (v) microbial load (microbial strains, physical state of bacterial strains, natural microflora, artificially inoculated microorganisms and population size).

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