OMSOTIC TREATMENT TECHNOLOGY AND EQUIPMENT
TEHNOLOGIJA OSMOTSKOG TRETMANA I PROCESNA OPREMA

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SUMMARY

In this paper the processing technology and equipment that may be applied on the industrial production scale for realization of Osmotic Treatment (OT) processes were presented. For testing of the industrial prototype of OT unit, processing of dry cherries and plums were chosen. Machines and Appliances of the processing line were specified and processes working parameters were defined. Technical solutions and construction of the OT Contactor were patented. The very specific features of the appliance have been approved during experimental long time runs, realized by use of the pilot plant scale unit. Pilot-plant experimental investigation also approved that, by use of the OT contactor, OT processes can be successfully applied practically on all known fruit commodities.

Key words: Osmotic treatment, process equipment, industrial scale prototype, unit for realization of continuous and controlled osmotic treatment processes, drying fruit by combining process of OT and convective air drying

REZIME

U radu su prikazani tehnološki postupci i procesna oprema koja omogućava realizaciju procesa osmotskog tretmana (OT) na industrijskoj proizvodnoj skali. Za proveru industrijske prototipne instalacije izabrani su tehnološki postupci proizvodnje sušenog voća, višnje i šljive. Mašine i uređaji tehnološke linije su specificirani, a radni procesni parametri se definisni. Osnovna tehnička rešenja i konstrukcija uređaja za kontrolisno izvođenje procesa osmotskog tretmana zaštićeni su patentima. Osobnosti rada uređaja su ispitivane i potvrđene na jedinici poluindustrijske skale. Takođe su ova ispitivanja pokazala da, se procesi osmotskog tretmana sa uspehom mogu primeniti na praktično sve voćne vrste.

Ključne reči: osmotski tretman, procesna oprema, industrijski prototip, jedinica za kontrolisno izvođenje procesa, kontaktor za osmotski tretman, kombinovanje osmotskog tretmana i konvektivnog sušenja voća

INTRODUCTION

Numerous well known fruit and vegetables preparation products from food industry as well as completely new ones, can be processed by combining Osmotic Treatment (OT) with traditional processing techniques. The recent increase in interest in OT arises primarily from the need for quality improved food products (Prothon F, 2003). Generally OT is applied with the aim of modifying the composition of food material through partial water removal and impregnation, without affecting the material's integrity (Torreggiani D, Bertolo G, 2001).

Realized laboratory and pilot-plant experimental investigations (Stevanović, R, Pavasović, V, 1984), (Pavasović V, 1981), (Pavasović V, Stefanović M, Stevanović R, 1986), (Pavasović V, Vereš M, Bicok K, 2000) resulted in the development of the processing technology and the equipment that may be applied on the industrial production scale without risks. The process of water removal is intensive and in comparison with the air drying is three to five times faster (Pavasović V, Stefanović M, 1978). As a consequence of this and some other facts, energy consumption and process costs are reduced up to 25%.

Besides the fact that among variety of products there are plenty of those that are more valuable and economically more profitable (high-quality ingredients, e.g. in yoghurt, ice creams and deserts, bakery fillings, fruit sauces, special jams, etc.) for testing of the OT equipment industrial prototype, dry fruit (dry cherries and plums) processing is chosen. Dry fruits are produced by combining two dehydration processes: osmotic dehydration and hot air convective drying.

CHERRIES AND PLUMS OSMOTIC DEHYDRATION

Dried fruits will be produced from frozen, stone free fruits. Processing is performed in series of the following groups of operations: pre-dehydration treatment, osmotic treatment and final product treatment.

Pre-Dehydration Treatment - In general, the treatment includes a sequence of operations that follows receiving and storing frozen fruits at the plant: unpacking and feeding the commodity to the processing line, de-clustering, inspecting and elevating commodity up to the check weighing conveyor of the Osmotic Treatment Unit.

Osmotic Treatment - It presents the initial dehydration process. During treatment, the raw commodity is introduced in an aqueous solution with relatively high concentration of dissolved natural substances, primarily contained in fruit. As a consequence of different concentration of dissolved substances in the fruit tissue cells and the surrounding liquid, and as well as the existence of semi-permeable cell membranes, the following processes are induced spontaneously:
- Water diffuses out of the tissue cells into the solution (dehydration process).
- Due to the removal of water, the cells shrink and intermolecular spaces become larger and are filled with solution. Definitely, a portion of large molecules from the solution diffuses into the cells through the existing pores of the cells membranes (uptake of dissolved substances or solid gain process).

Osmotic treatment is realized continuously (Pavasović V, Stevanović R, 2004). The osmotic-active agents, following high concentrated solutions or the mixtures thereof are proposed as follows:
- Sucrose aqueous solution (60-70% of dry matter content weight) and
- Grapes juice concentrates (approximately 70% of dissolved dry matter content weight).

The process will be carried out at temperatures in the range 60-70°C. Process intensity is supported by agitation realized by combining mechanical hydraulic mixing. The flows of the osmotic-active solution and the fruit pieces are countercurrent.
Contact times of the fruits and the osmotic-active medium are: 1. for cherries from 1 to 1.5 hours and 2. plums from 2 to 3 hours. Obtained dehydrated fruit will have the concentrations of dissolved dry matter contents weight from 50 to 57%.

Osmotic-Active Solutions Preparation - Crystalline sucrose-commercial grade is dissolved in hot water. The intensity of dissolution is increased by heating and circulating the suspension of crystals in water in closed system. When the process is finished, some concentrated citric acid solution is added with the aim to keep fruit acidity unchanged. Grape juice concentrate is prepared simply by circulating, heating and adjusting the acidity of solution and by adding some citric acid if necessary.

Osmotic-Active Solution Purification - During the osmotic treatment of slight fruit pieces, mechanical damage occurs. As a consequence of this process small fruit tissue particles remain in the solution and accumulate with time. Purification of the solution is done by the separation of suspended particles. For this purpose continuous filtration is performed on the side stream of the main osmotic-active solution flow. Separated solids are continuously removed from the system.

Osmotic-Active Solution Regeneration - During the osmotic treatment osmotic-active solution is diluted by water transferred from fruit to the surrounding liquid phase. Furthermore, some soluble substances from the fruit tissue cells are leaked out as well. To keep the potential of the osmotic-active medium, a portion of water is eliminated from the solution continuously. The process of vacuum evaporation of the diluted solution is performed for this purpose. Continuous vacuum evaporation process re-concentrates osmotic-active medium and prolongs its usage.

Final Product Treatment - Osmotic treated cherries and plums are additionally dehydrated by convective hot air drying process. Air drying, as a second dehydration step, is performed in order to concentrate the dissolved dry matter weight into the fruit of up to 70%. The corresponding water activity values of dry fruit products are in the range from 0,85 to 0,90. For permanent preserving of the corresponding foodstuffs, it is necessary to protect them with chemical preserving additives. For this purpose diluted aqueous solution of potassium sorbate (0.5 weight %) is recommended. The concentration of salt in the final product weight is up to 0.1%. If dry products are packed adequately, thermal preserving process-pasteurization can be successfully applied without use of any chemical additives. The sequence of operations that follows osmotic treatment process consists of:

1. Rinsing fruit pieces by warm water, dewatering by high speed air stream, loading the trays with fruits, loading the trolleys with prepared trays, inserting the trolley in to the tunnel type dryer, drying the fruit periodically, discharging the tunnel dryer, unloading the trolleys as well as the trays, feeding the conveyor with dry fruits, spraying the additive solution on the fruits surface and packing.

PROCESSING LINE EQUIPMENTS AND APPLIANCES SPECIFICATION

Dry fruits processing line consists of following operating units: 1. Fruit preparation (pre-dehydration unit), 2. Osmotic treatment unit, 3. Air drying unit and 4. Packaging unit. Processing line also includes the following supporting-auxiliary units: 1. Air compression unit, 2. CIP unit and 3. Steam generating unit.

Operating units

1. Fruit Preparation-Pre-Dehydration Unit

Machines and appliances of the unit are used for the purpose of achieving the pre-dehydration treatment operations. When the frozen fruits are used as raw commodities, the unit is composed of the following machines: 1. Inspecting conveyor, 2. Elevating conveyor and 3. Check weigher.

All of these machines are offered and manufactured all around.

2. Osmotic Treatment Unit

The unit is used for the osmotic treatment processes which include: preparation of the osmotic-active solutions, osmotic dehydration, osmotic-active solutions purification, osmotic-active solutions regeneration and for osmotic-active solutions storing. The unit is automatically operated. Processes of: osmotic dehydration, osmotic-active solution purification, and osmotic-active solutions regeneration are performed continuously.

Operational characteristics of the unit are:

- Capacity of fruits and vegetables dehydration, when the low increases of the dissolved dry matter content weight from 15 to 30% is obtained, are: up to 1,000 kg /h of fresh or frozen raw commodity.
- Capacity of of water removal from raw commodity is: up to 400 kg /h.
- Minimum dehydration time is 15 min.
- Maximum dehydration time is not limited.
- The average energy consumption is 3.400 KJ per kg of removed water.
- Capacities of osmotic dehydration for cherries and plums in dry fruit processing, are: up to 430 and 215 kg /h of fresh or frozen raw commodities.
- Osmotic treatment processes can be performed in temperature ranges from 40°C to 80°C.

Osmotic Treatment Unit consists of the following operating systems: System for preparation of the fresh osmotic-active solutions, System for purification of the osmotic-active solutions, System for storing of the used osmotic-active solutions, Continuous osmotic treatment contactor (OTC) and System for the used osmotic-active solution vacuum evaporation.

3. Fresh Osmotic-Active Solutions Preparation System

The system consists of:

- 1.000 liters capacity tank thermally isolated,
- Cast stainless steel circulating pump,
- Stainless steel plate exchanger, thermal power 70 kW,
- Cast stainless steel pump, used for delivery of the fresh osmotic-active solution. The pump capacity is 5 m³/h of osmotic-active solution, discharge pressure is 3 bars, sealing of the shaft is by flushing water,
- Automatically operated multi element filter with porous stainless steel tubes. Capacity of filtration is up to 5m³/h, diameter of tube pores is less than 5,0 x 10⁻⁷ mm.
- 1.000 liters capacity tank, used for balancing the required volume of osmotic-active solution, thermally isolated, with level and temperature indicators and connectors,
- Stainless steel plate exchanger, maximal thermal power 350 kW,
- OTC osmo-active solution feeding pump, driven by geared motor with integrated frequency inverter (pump is of volumetric type, capacity 15 m³/h, sealing of the shaft by flushing water),
- Drum and barrel emptying pump,
- Drum and barrel electrically heated mantle,
- Pipes, valves, fittings, necessary parts and connectors for use of the CIP system, electric panel for thermostatic and flow control.

4. Process Parameters Measurements and Control is consists of:
5. Osmotic-Active Solution Purification System

The system consists of: automatically operated self cleaning continuous filter. Filtration capacity is up to 15 m$^3$/h, separated particles diameter is over 0.5 mm.

6. Used Osmotic-Active Solutions Storing System

The system consists of:
- Two 1,000 liters capacities thermally isolated tanks,
- Cast stainless steel circulating pump,
- Stainless steel plate exchanger, thermal power 70 kW,
- Cast stainless steel delivery pump, 5 m$^3$/h of osmotic-active solution capacity, discharge pressure is 3 bar, shaft sealing by flushing water,
- Pipes, valves, fittings, necessary parts and connectors for use of the CIP system, electric panel for thermostatic and flow control.

7. Process Parameters Measurements and Control
- Measuring and control of the constant temperature of the liquid outlet flow from plate heat exchanger,
- Measuring and control of the used osmotic-active solution inlet mass flow in,
- Control of the pumps working parameters.

Continuous Osmotic Treatment Contactor

The special feature of the OT contactor is that it allows contact of a fragile, damage sensitive, solid phase with an often denser and usually high viscous liquid phase. It belongs to the class of vertically positioned cylindrical column type appliances, with continuous or intermittent combined mechanical and hydraulic mixing of liquid phase in which the solid particles are discretely distributed. Agitation of two said phases can be performed with several types of mechanical mixers, placed inside the cylindrical column and which are, by use of driving mechanisms, brought to a reciprocating or a simultaneously reciprocating and rotating motion (Pavasović V, Stevanović R, 2004). OT contactors used for preparation of food raw materials fulfill the following functional requirements with respective assessment criteria (Marouze C, Girox F, Collinian A, Rivier, M, 2001):

Function:
- allowing solid food to be contacted with liquid phase consisting of solutions with a high concentration of solutes.

Assessment criteria:
- creating relative movement between the solution and the food, characterised by relative velocity and homogeneity for all the food,
- handling food with almost negligible mechanical damage,
- control of treatment time and, for equipment used for continuous processing, spread of residence times (SRT) in the contactor to ensure homogeneous treatment of the food (Stevanović R, Pavasović V, Ćokeša D, 2003),
- ability to accept different food shapes (whole, halves or cubes, slices and other forms),
- ability of processing fresh, previously frozen, or temporarily cold-stored raw materials,
- reduction of solution mass/food mass ratio (a low ratio is of particular interest if the cost of solution is high, and it also diminishes equipment size),
- avoidance of oxidation reactions in food by excluding contact with air.

Function:
- allowing the solution to be introduced and removed.

Function:
- allowing the food to be introduced and removed (for continuous processing: continuous introduction, and removal of food when it has reached the required stage of treatment).

Function:
- for continuous processing, allowing counter-current or co-current flow of the food and the solution.

Function:
- complying with the appropriate mechanical, electrical and food-related standards.

OT contactor consists of: - Cylindrical column (inside diameter 500 mm, high 2,500 mm), - Bottom column disengaging section, - Top column disengaging section, - Perforated disk mixer, - Mixer's driving mechanisms, - Food feeding weight dosser, - Food inlet leg, - Cast stainless steel circulating pump, 5 m$^3$/h of osmotic-active solution capacity, discharge pressure 3 bars, sealing of the shaft by flushing water, - Treated food discharging assembly, - Food discharging weight dosser, - Solution overflow discharge, - Treated solution outlet and contactor drain, - Osmotic-active solution inlet, - Used solution discharging pump, driven by geared motor with integrated frequency inverter (pump is of volumetric type, 15 m$^3$/h, capacity, sealing of the shaft by flushing water), - Pipes, valves, fittings, necessary parts and connectors for use of the CIP system, electric panel with corresponding control systems.

1. Process Parameters Measurements and Control
- Measuring and control of solid particles inlet and outlet mass flows (QC),
- Measuring and control of the used osmotic-active solution outlet flow (FT, FIC, and FICA),
- Measuring and control of the osmotic-active solution flow in food inlet leg (FT, FIC),
- Control of the pumps working parameters.

Used Osmotic-Active Solution Vacuum Evaporation System

This system is used for the regeneration of osmotic-active solutions. During the OT process, osmotic-active solution is diluted by water transferred from fruits or vegetables into the surrounding liquid. In order to regenerate osmotic-active solution and eliminate some water from it, flash vacuum evaporation process is performed. Vacuum evaporation system consists of:
- Vapor-mist separator, up to 400 kg/h, water evaporation capacity, working pressure: from 70 to 150 mbar, boiling temperatures from 40 to 65°C. Separator is cylindrical, 600 mm in diameter, 2,500 mm high, thermally isolated, poses: liquid level, temperature and pressure indicators.
- Cyclone mist separator, 400 mm diameter, 1.100 mm height.
- Pump used for spraying the diluted osmo active solution. It is driven by geared motor with integrated frequency inverter.
(pump is of volumetric type, 25 m³/h capacity, discharged pressure up to 3 bars, sealing of the shaft by flushing water),
- Pump used for discharging of the Vapour-mist separator. It is driven by geared motor with integrated frequency inverter (pump is of volumetric type, 25 m³/h capacity, discharged pressure up to 3 bars, suction head minimum 2 m water gauge, sealing of the shaft by flushing water),
- Appliance for condensation of vapor is Condense Tower offered and manufactured all around.

Process Parameters Measurements and Control are:
- Measuring and control of the constant liquid level,
- Measuring and control of the constant gaseous phase pressure in liquid level,
- Measuring and control of the constant temperature of the liquid outlet flow from plate heat exchanger,
- Measuring and control of the osmotic-active solution flow into vacuum evaporator,
- Control of the pump's working parameters.

**Air Drying Unit**

Machines and appliances of this unit are offered and manufactured all around. This unit consists of: - Water rinsing machine, - Dewatering conveyor, - Auto on tray drying tunnel, - Semi auto tray loader 'un-loader.'

**Packing Unit**

Machines of this unit are offered and manufactured all around. Auxiliary units present standard equipment type, offered and manufactured all around.

**CONCLUSION**

By combining OT with traditional processing techniques it is possible to process numerous well known fruit and vegetable preparation product of the improved quality. Technical solutions of the machines and appliances of the prototype industrial unit provide that the OT processes can be performed continuously and completely controlled. Beside this, OT processes are realized very intensive and due to it energy consumption as well as total processing cost can be noticeable reduced.

**LITERATURA**


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