PROGRESS

Promoting Green Deal Readiness in the Eastern Partnership Countries

НУБіП 1898

Effective technologies for storing and processing garden strawberries using best environmental practices

Oksana ZAVADSKA

Candidate of Agricultural Sciences, Associate Professor, Department of Storage, Processing, and Standardization of Plant Products named after Prof. B.V. Lesik National University of Life and Environmental Sciences of Ukraine
zavadska@nubip.edu.ua

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The State of the Industry, Challenges, and Prospects

Every year, Ukraine produces between 56,000 and 62,000 tons, with about 80% of that being sold fresh on the domestic market

A short processing window—2–3 months

Vertical farming: The future lies with farms that have their own fields and processing facilities on-site, allowing them to avoid dependence on raw materials and seasonal fluctuations

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Characteristics of garden strawberries as a crop for storage and processing

Garden strawberries enter storage already physiologically ripe; they do not enter a natural state of dormancy, breathe rapidly, and lose moisture through evaporation. The most dangerous disease—gray mold—can appear as early as 12 hours after harvest!

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Characteristics of garden strawberries as a crop for storage and processing

Strawberries – a raw material that demands speed. For high-quality processing, the berries must be fed into the freezing tunnel or dryer as soon as possible after harvesting

The aroma has low thermal stability—it contains more than 300 aromatic compounds and is lost during heat treatment

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Techniques for Storing Garden Strawberries

Designed to slow down metabolic processes as much as possible after harvesting

Pre-cooling – a green practice!

Processing should be done as soon as possible—no later than 1–2 hours after harvesting. Delaying cooling by 1 hour reduces the berries' shelf life by 1 day.

Cooling method – forced-air cooling, with air blown through stacks of crates (Forced-Air Cooling). A rapid-cooling chamber, powerful fans, and perforated crates are used.

Temperature objective: to lower the temperature of the berries from +25°C to +2°C...+4°C. At +22°C, strawberries lose their marketable appearance after 12–15 hours.

Once the berries have cooled, it is important to avoid reheating them—condensation may form.

Post-processing steps should be carried out at a temperature of +4°C.

Key requirements for varieties: high organoleptic qualities, weight (25–35 g)Shippability:Albion, Clery, Rumba

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Techniques for Storing Garden Strawberries

Under normal atmospheric conditions	• Monitoring of temperature and vital signs Duration: 3–5 days
Under modified atmosphere (MA/MAR) conditions	• Using selectively permeable films and coatings Duration: 10–14 days
Under controlled atmospheric conditions (CA)	Carbon dioxide content: 10–15% (sometimes up to 20%); oxygen: 2–3% (chambers, airtight bags) Duration: 15–28 days

The relative humidity should be 90–95%, the temperature should be 0°C … +0.5°C, with minimal fluctuations in humidity and temperature

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The use of edible films

Over the past five years, the use of edible films has been growing rapidly due to the demand for eco-friendly products and waste reduction

Chitosan coatings (derived from the exoskeletons of crustaceans or fungi)

They form a thin, semi-permeable film that traps carbon dioxide inside the berry and have fungicidal properties

Alginate (seaweed) and pectin films (apple/citrus pectin)

They create a dense moisture barrier and provide mechanical protection against cracks; antioxidants (ascorbic acid) are often added to prevent darkening

Coatings based on lipids (vegetable oils), wax (beeswax), aloe vera, etc.

Advantages:
- extended shelf life of up to 12–18 days
- no plastic—the films themselves act as a gas barrier (reducing energy consumption);
- safety (clean label) natural film composition (pectin, starch, cellulose)

In Ukraine, this technology is used by farms that export fresh strawberries to the EU and the Gulf countries

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The Palliflex Berry Storage System

Advantages

Insolar is the official representative of the system manufacturer (the Dutch company Van Amerongen). A single pallet can hold 400–1,000 kg of product

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Reusable packaging. Pooling

Pooling (from the English word “pooling”) is a system for renting and sharing reusable packaging (primarily plastic crates and pallets); a closed-loop economy concept

Container turnover cycle: rental – berry harvesting – cooling – distribution center – retail network – return – service

International Fruit Container Organization (Міжнародна організація фруктових контейнерів) *https://www.ifco.com/ - модель **RPC 6410** 600 x 400 x 100 мм.

Benefits, results

- **- Standardization and unification – dimensions that are perfectly suited for Euro pallets and Palliflex or MAP packaging systems;**
- **- Ventilation – perforated walls suitable for pre-cooling;**
- **- Environmental friendliness – one plastic crate replaces up to 100–120 cardboard boxes over its service life (over 10 years), after which it is recycled into a new crate;**
- **- Reduces CO2 emissions by 62% and solid waste by 96%***

Major suppliers of reusable plastic containers: IFCO Systems (300 million crates), Euro Pool System (EPS) https://www.europoolsystem.com/about-eps/

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Ozonation as a green practice

Ozone (O_3) is a powerful oxidizing agent that acts 3,000 times faster than chlorine, destroying bacteria, viruses, and fungal spores (including Botrytis cinerea, the pathogen responsible for gray mold); it rapidly breaks down into pure oxygen, leaving no chemical residue

Ozonation of washing water (aqua-ozonation)

Ozone dissolves in water, creating a sterile environment, and breaks down into oxygen after 15–20 minutes

Ozone treatment of the air in the cold storage room

Prevents mold growth and neutralizes ethylene, extending shelf life by 2–4 days

Disinfection of equipment and processing lines

It allows you to reduce the use of harsh cleaning chemicals and conserve water, since ozone does not require prolonged rinsing and the wastewater does not need to be chemically treated

Ozone is produced by special generators (ozonizers) from the surrounding air through an electrical discharge

Ozone is toxic to humans at high concentrations (it irritates the respiratory tract), so ozonation systems must be equipped with monitoring sensors

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Use of electric vehicles

It ensures energy efficiency, reduces the carbon footprint, and prevents quality loss in finished products; the transition to electric vehicles is a food safety requirement at processing plants

There must be no exhaust fumes in the storage rooms where the berries are kept

Electric motors generate less heat – maintaining a stable temperature in refrigerators

Electric cars do not leave oil or fuel stains on the floor, which is a mandatory requirement of HACCP

Ideal for narrow passages between berry sorting and washing lines

Electric palletjacks – for lifting pallets

Pallet trucks— move pallets weighing 1–2 tons

Reach trucks - forklifts designed for use in cold storage facilities

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Main Areas of Strawberry Processing

Strawberries often lose their shape during thawing. Therefore, it is more cost-effective to produce homogenized aseptic puree, which serves as a base ingredient for the largest food conglomerates

Processing sector	Intended use
Purees, concentrates	A base for yogurt, juice, ice cream, and baked goods (stable domestic demand)
Freezing* (IQF and block freezing)	Export (IQF whole, graded berries), retail chain, puree, smoothies
Jams, preserves	Fillings for croissants and cookies, and a retail chain
Freeze-drying and drying (freeze-dried snacks, fruit leather)	Premium dry breakfast foods (muesli, granola), teas, chocolate, freeze-dried ice cream, Healthy Food Market

*Frozen strawberries account for the bulk of Ukraine's exports to the EU. Shelf life: up to 24 months (at -24°C).

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Factors Affecting the Quality of Processed Strawberries

Organization of harvesting, cooling rate to a temperature of +2 to 4 °C

- There is a critical need for pre-cooling chambers close to the field

Raw material quality – grade selection

- Technological, organoleptic, physicochemical, and sanitary-hygienic criteria—absence of impurities, sand, pests, moisture, pathogens, and pesticide residues

The quality of raw material preparation and the processing technology used!

Dosing, packaging, final quality control

Storage conditions, logistics

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Selection of raw materials for processing

Using varieties adapted to climate change will ensure predictable yields and the opportunity to receive a grant to offset the cost of seedlings.

Zenga Zengana	Dark flesh, holds its shape, rich aroma
Honey	Consistent shape and color
Shelf	High pulp density, high sugar content
Alba	Perfect market appearance; used for freezing whole berries

Thermal stability: the ability to retain color and aroma when heated

The most common variety used for processing in Ukraine and around the world is the Senga Sengana variety (Germany)

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The production stages of mashed potatoes

Quality requirementsBrix – 7–12%; uniform texture, no traces of stems or peel

Boema (Italy) and PB Engineering Ukraine offer a complete production cycle (from washing to aseptic filling)

Raw material preparation: cleaning – washing – inspection – blanching (at 85–90°C) – straining (passing the pulp through 0.8 mm screens for seedless puree or up to 4 mm for puree with seeds)

Vacuum deaeration, aroma condensation (t - 45–60°C) - atomization of the puree in a deep-vacuum chamber (preservation of color and aroma, prevention of separation, extension of shelf life)

Heat treatment (pasteurization): Rapid heating to 92–95°C (holding time 30–90 seconds) – immediate cooling to 20–25°C

Aseptic filling: The puree is fed into a sterile chamber, where it automatically fills aseptic sterile bags (Bag-in-Box); stored at +10–15°C for 12–18 months without preservatives or refrigeration (minimal carbon footprint)

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The stages of jam production

Texture: a uniform, thick, gel-like mass that does not spread; the berries do not need to be intact; dry matter content: 65–68%

Raw Material Preparation
- Coarse grinding (crushers, pieces 5–10 mm in size)
- Homogenization (grinding machines)

Boiling:
Vacuum cookers must be used because the high density of the mixture causes it to burn quickly in open pots; cooking time is 30–45 minutes

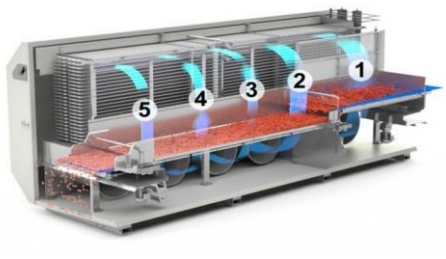
Adjusting consistency and clarity
- adding pectin and ascorbic acid
- LM pectins are added to heat-stable fillings and low-sugar diet jams

Deaeration (removal of air)
- At the end of cooking in the vacuum machine, the vacuum is sharply increased for 2–3 minutes
- The jam becomes clear, does not oxidize, and does not separate

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Comparison of Freezing Technologies

	Static freezing, chambers	IQF fluidization, tunnels
How it works	Freezing in a stationary position on trays or carts in a forced-air chamber.	Freezing in a suspended state on perforated trays
Duration of the process	3–5 years	8–15 minutes
Product quality/market category	May be misshapen or clumpy / raw material for purees, jams, and juices	Perfect crumbly texture, premium-quality products,higher price (20–50% more)
Equipment Performance	15–250 kg/hour, depending on the chamber volume	from 500 kg (minimum) to 5 tons per hour
Suitability	For small businesses – raw materials for processing, HoReCa	for professional export-oriented manufacturers



The stages of IQF freezing

Produce is pre-cooled in rapid-cooling chambers to +2...+4°C

Raw material preparation: washing (air-jet washers), cleaning, stem removal, sizing (25–35 mm), pre-drying

IQF freezing process in a tunnel: temperature -35… -42 °C, air velocity 5–10 m/s, 10–15 minutes; the temperature of the berries at the exit should not exceed -18 °C

Optical sorting, metal detection

Weighing and packaging (retail – 300–400 g; 2.5 kg – HoReCa, 10 kg – pastry shops, export), metal detection (final inspection)

Cold storage and logistics at temperatures of -18 to -22 °C* (over 6 months at -24 °C) **(high carbon footprint!)**

*Even a brief drop in temperature to -12 °C causes the berries to stick together!

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The Benefits of Drying Garden Strawberries

All-natural **– no artificial colors or preservatives added**

Nutritional and energy value: **a concentrate of beneficial substances**

Logistical convenience **– they require 6–8 times less space and packaging compared to fresh or frozen products (low carbon footprint)**

- ***Long shelf life: 12 months or more when stored according to recommendations (5 years for freeze-dried products)***
- ***Ideal raw material for the production of functional foods****

**** Functional foods are foods that contain specific ingredients designed to improve health or reduce the risk of certain diseases.***

PROGRESS
Promoting Green Deal Readiness in

Comparison of Drying Technologies

Drying method	How it works	Advantages	Disadvantages
Airy and sunny	Sunbeams	Low costs	Weather dependence, risk of contamination, poor quality, color fading
Convective	Warm air (45–60°C)	Accessibility, simple automation, differentiation	Risk of burning and loss of biologically valuable substances
Infrared (fryps, pastila)	Infrared rays (without heating the air)	Drying speed, disinfection (sterilization)	High costof IR lamps. Risk of uneven drying
Sublimation	Freeze-drying under high vacuum	Retains 98% of vitamins, shape, color, and crunch	High equipment costs, high energy consumption

During the drying process, it is critical to minimize excess moisture. Growing berries on mulch fiber eliminates the need for washing, which significantly saves energy

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Basic freeze-drying processes(Freeze-drying)

Receipt and Preparation of Raw Materials

Inspection and selection of whole, ripe berries

Cleaning, calibration

Flash freezing – berry temperature: -40°C

The process of sublimation – the evaporation of ice

Drying to a moisture content of 2–5% – do not exceed a temperature of 45°C! (causes discoloration)

Packaging – high-barrier materials,

(Doy-pack with a zipper – retail, glass, and metal airtight jars)

Raw material requirements: soluble solids content of at least 9%, firm flesh, uniform color

Because of their large size, freeze-drying whole strawberries takes a very long time (48 hours or more), so strawberries are often freeze-dried in slices (3–5 mm thick)

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The Benefits of Pastila as a Processed Food

- Pastila is a product that can be made locally using local ingredients. This makes it possible to support local producers and reduce the carbon footprint.
- Pastila is an ideal product for artisanal production, as it does not require significant initial capital investment and allows for the creation of exclusive flavors

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The production stages of pastila

Raw material preparation: inspection, washing, cleaning, mandatory sifting (0.5–0.8 mm sieve)*

Production of puree – vacuum evaporation at a temperature of 45–50°C until the dry matter content reaches 12–16%

Blending - adding ingredients according to the recipe*

Re-boiling (if necessary), deaeration (vacuum deaerator), or settling (1–2 hours)

Drying (dehydration) at a temperature of 45–55 °C

Cooling, presentation, packaging

Adding 30–50% apple puree ensures elasticity and a firm texture, while citric acid helps stabilize the color

***Насіння суниці при висушуванні стає дуже твердим і може створювати відчуття "піску" на зубах**

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Off-grid power supply

Comparison of Technologies

	Industrial solar power plants ("green energy") – (Agro-Frost, Tevitta, Eco Berry, etc.)	**Cogeneration plants (biofuel)** (T.B. Fruit, large agricultural holdings)
Key Benefits	Free energy during the day covers 40–70% of the plant's electricity needs precisely during peak loads, reducing its carbon footprint!	Generates electricity and heat. Not dependent on weather or the grid; operates efficiently year-round (ideal for cold storage rooms); provides heat (88–92% efficiency)

Roof-mounted solar power plants are more popular among processing plants, as cold storage facilities and freezing rooms have vast roof areas. In addition, the panels protect the roof from overheating in the summer, which further reduces the cost of cooling the building.

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Anti-HFC technologies

Aimed at reducing the use of hydrofluorocarbons (HFCs), which are powerful greenhouse gases (freon), to reduce the carbon footprint

Features of the technology

- **Ammonia is effective for cooling and freezing,** offers the lowest cost per kilowatt-hour of cooling, and has zero ozone-depleting potential
  Carbon dioxide is used in refrigeration systems in cold storage rooms; it is ideal for flash freezing and freeze-drying, and can be used to produce hot water

Replacing high-fructose corn syrup with natural carbohydrates can reduce the environmental impact and increase production efficiency by 10–15%

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Eco-friendly packaging

A Comparison of the Most Common Packaging Options for Different Types of Products

Parameter	**Frozen**	**Freeze-dried**	**Mashed potatoes**
Key requirement	Frost resistance, moisture barrier, durability	Waterproofing, lightproofing, airtightness	Air-tightness and oxygen barrier, high barrier properties
The best eco-friendly option is single-material*	Cardboard packaging with bio-plastic insert bags	Monopolyethylene doypack (manufactured by Aris and AITAK using a single material (Full PE))	TECHNOLOGIA Aseptic Bag-in-Box Packaging (2–1,000 L)(https://technologia.com.ua/)

*Use of mono-materials (Mono-PE—polyethylene) that are 100% recyclable and reduce the amount of plastic per unit of product. Payback period: up to 2 years (https://www.smithers.com/services/market-reports/packaging/future-of-mono-vs-multi-material-packaging-to-2028)

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Water recycling

The creation of closed-loop water supply systems, in which water continuously circulates between different stages of production after appropriate treatment—including filtration, ultrafiltration, UV disinfection, or ozonation.

*https://techhorticulture.com/u-prioryteti-ekonomiya-vodnyh-resursiv-i-povtorne-vykorystannya-ochyshhenoyi-vody/

Key Benefits

Adaptive	For socio-economic development
A 50–90%* reduction in the need for fresh water; a decrease in the volume of wastewater requiring treatment; lower costs for heating and cooling water due to temperature stabilization in closed-loop systems	The ability to conduct economic activities in the context of climate change (jobs, wages, taxes).

Implementation: Installation of water collection, filtration, and reverse osmosis systems that enable the purification of water used to wash berries, containers, and production lines, allowing for its reuse;The technology is available in Ukraine, with a payback period of 2–4 years

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The use of sustainable practices in the storage and processing of strawberries

Practice	Implementation	Result/benefit
Rainwater harvesting	Collecting rainwater in tanks and using it for industrial purposes: washing containers, raw materials, processing lines, lids, etc.	A 30–50% reduction in water supply costs compared to using centralized sources
Heat recovery from refrigeration systems	Installation of heat recovery systems that channel this heat for water heating, industrial use, and the freeze-drying process of berries	Free hot water for washing berries, conveyor belts, containers, and staff showers; heat for drying berries—energy savings
Zero-waste technologies and waste recycling—the principle of the circular economy	Processing into puree, concentrates, and flavor concentrates; extraction of anthocyanins for dye production; production of strawberry flour for snack bars; composting of organic waste	Converting by-products from one process (waste) into resources for another.Maximizing the use of raw materials and generating additional revenue

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

The use of sustainable practices in the storage and processing of strawberries

Freezing “cooling agents” (ice or special gels) overnight can save up to 40% on electricity!

The use of sandwich panels (polyisocyanurate) with a thickness of 150–200 mm is standard for frozen food storage rooms (-18°C to -25°C)

Optimizing freezing and drying times using AI-based control systems real-time analysis of product moisture content, automatic shutdown when the desired moisture level or temperature is reached

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Implementation of green practices at Ukrainian processing plants

Agrana Fruit (Vinnytsia)

- A leader in the production of fruit fillings for yogurt (Danone, Molokiya, etc.)
  Uses aseptic pouches, heat recovery, reusable containers, and SES

Eco-Berry (Ivano-Frankivsk Oblast)

- They handle the entire process: from cultivation to freezing and processing into mashed potatoes, SES, and organic products

Panfruit (Poltava Oblast)

- We freeze-dry whole berries, slices, and powder (made from substandard berries); we use eco-friendly packaging (doy-packs), reuse water, and employ automated washing systems

Blueberry (Zakarpattia Oblast)

- Equipped sorting lines where waste (stems/small berries) is separated for further drying or composting

PROGRESS
Promoting Green Deal Readiness in the Eastern Partnership Countries

Strategic Directions for the Development of Berry Processing Enterprises in the Context of Climate Change

In the face of global warming and unpredictable rainfall, the berry processing strategy is shifting from simple processing to high-tech, resource-efficient production

Energy Efficiency and Renewable Energy	• Using solar power systems to offset peak loads in the summer Heat recovery for water heating
Water Resources Management	• Closed-loop systems (recycling) Ozonation, on-site treatment plants
Waste Reduction and Recycling (Zero Waste)	• Processing into purees, fillers, flavor concentrates, natural colorants, etc.
Standard packaging	• Eco-friendly packaging Reusable containers
Adapting standards to "organic" and "sustainability"	• Verification of product safety, carbon footprint, traceability, and transition to natural refrigerants

PROGRESS

Promoting Green Deal Readiness in the Eastern Partnership Countries

НУБіП 1898

THANK YOU FOR YOUR ATTENTION!