PROGRESS

Promoting Green Deal Readiness in
the Eastern Partnership Countries

ADAPTATION OF POST-HARVEST TECHNOLOGIES FOR APPLES TO GLOBAL CLIMATE CHANGE

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Lyudmila Shevchuk

Professor, Department of Horticulture named after Prof. V.L. Symyrenko, National University of Life and Environmental Sciences of Ukraine

Doctor of Agricultural Sciences

Corresponding Member of the National Academy of Agrarian Sciences of Ukraine

l.shevchuk@nubip.edu.ua

ADAPTATION OF POST-HARVEST TECHNOLOGIES FOR APPLES TO GLOBAL CLIMATE CHANGE

1. Adaptive post-harvest technologies for apple production

2. Harvesting and primary processing of apples

Determining optimal harvest times and crop quality

Climatic factors influencing microbiological diseases and functional disorders in apples

Post-harvest processing chains for apples

3. Storage and disinfection

Eco-friendly disinfection of fruit storage facilities

Pre-cooling – Modern eco-storage technologies

4. Industrial processing – value-added strategy

- Apple concentrate – eco-scheme - Pectin — deep processing of waste

5. Energy conservation and recycling

STRUCTURE OF THE APPLE MARKET

STRUCTURE OF THE GLOBAL APPLE MARKET

- 70–75% fresh market
  - 60–80% of apples are stored
  - 20–40% are sold directly from the orchard
- 30–25% recycling
  - 65–70% apple concentrate
  - 12–15% cider, other beverages
  - 8–10% mashed potatoes
  - 6–10% (chips, powders, pectin, etc.)

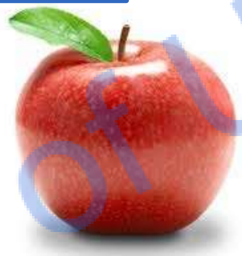
STRUCTURE OF THE UKRAINIAN APPLE MARKET

- 40–50% of the fresh produce market
  - 60–70% of apples are stored
    - 30–40% ULO storage
    - 40–50% Storage ZA
  - 30–40% are sold directly from the orchard
- 30–50% recycling
  - 75% apple concentrate
  - 12% mashed potatoes
  - 13% (chips, powders, pectin, etc.)

ADAPTIVE POST-HARVEST TECHNOLOGIES FOR APPLE PRODUCTION

FRESH MARKET

- Cooling
- Storage
- Eco-packaging



PROCESSING

- Primary (concentrates, juices, purées)
- Secondary (pectin)
  - Biofuel, dietary fibre

Closed-loop water management:
Water treatment and reuse after apple washing (reverse osmosis systems and UV disinfection)

CHECKLIST FOR OPTIMAL STORAGE OF APPLE FRUIT

- PRECISION MONITORING OF RIPENESS
  - Monitoring of active temperature sums above 10 °C
    - 2400–2800 °C for late-ripening varieties
  - Degree of starch degradation
    - (5–8 points)
  - Flesh firmness
    - (8–12 kg/cm²)
  - SSP content
    - not less than 12%
  - Endogenous ethylene concentration
    - not more than 0.5 ppm
- RATIO OF MACRO- AND MICROELEMENTS $(K+Mg^{2+})/Ca^{2+} < 25$; $N/Ca^{2+} < 10$; $Ca^{2+}/Mg^{2+} > 0.5$

CHAINS FOR POST-HARVEST PROCESSING OF APPLES for the fresh market

COOLING
SORTING
TREATMENT WITH INHIBITORS AND FUNGICIDES
STORAGE
PACKAGING
SALES

COOLING
TREATMENT WITH INHIBITORS AND FUNGICIDES
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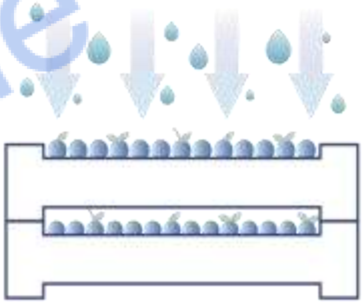
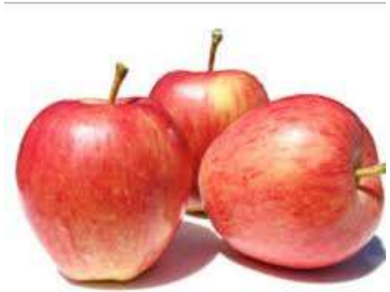
SALES

COOLING



- **Cooling using a stream of air blown through containers of fruit (to 2–4°C, for 7–8 hours)**



- **Cooling, combined with sorting in ice water, helps prevent wilting**

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PHYSICAL CHARACTERISTICS OF APPLE FRUIT

DSTU UNECE FFV 50				DSTU 8133
Size	PREMIUM grade	Standard	not less than 65 mm	not less than 70 mm
		large-fruited	-//- 70 mm	
	I-Y	standard	-//- 60 mm	-//- 65 mm
		large-fruited	-//- 65 mm	
	II	standard	-//- 60 mm	-//- 50 mm
		large-fruited	-//- 65 mm	
Weight	HIGHEST market grade	standard	-//- 90 g	
		large-fruited	-//- 110 g	
	I	standard	-//- 80 g	
		large-fruited	-//- 90 g	
	II		-//- 70 g	

REQUIREMENTS FOR THE COLOUR OF APPLE FRUIT IN ACCORDANCE WITH DSTU UNECE FFV 50

- Colour group A (coloured fruit)

Superior grade	3/4 of the fruit
Grade I	1/2 of the fruit
Grade II	1/4 of the fruit

(Rubinstar, Lodel, Spurovi and 'Red' group varieties)

- Colour group B (fruits with uneven colouring)

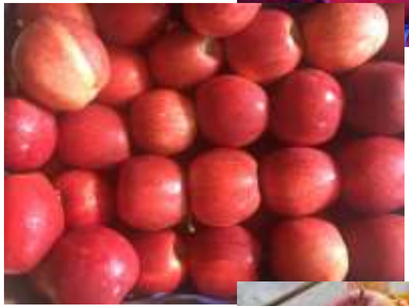
Superior grade	1/2 of the fruit
Grade I	1/3 of the fruit
Grade II	1/10 of a fruit

(Idared, Gloucester, Ligol, Gala clones)

- Colour group C (lightly coloured fruit)

Superior grade	1/3 of the fruit
Grade I	1/10 of the fruit
Grade II	Not standardised

(Honeycrisp, Melba, Wilmette, Melrose)


MONILIOSIS

GRAY ROT

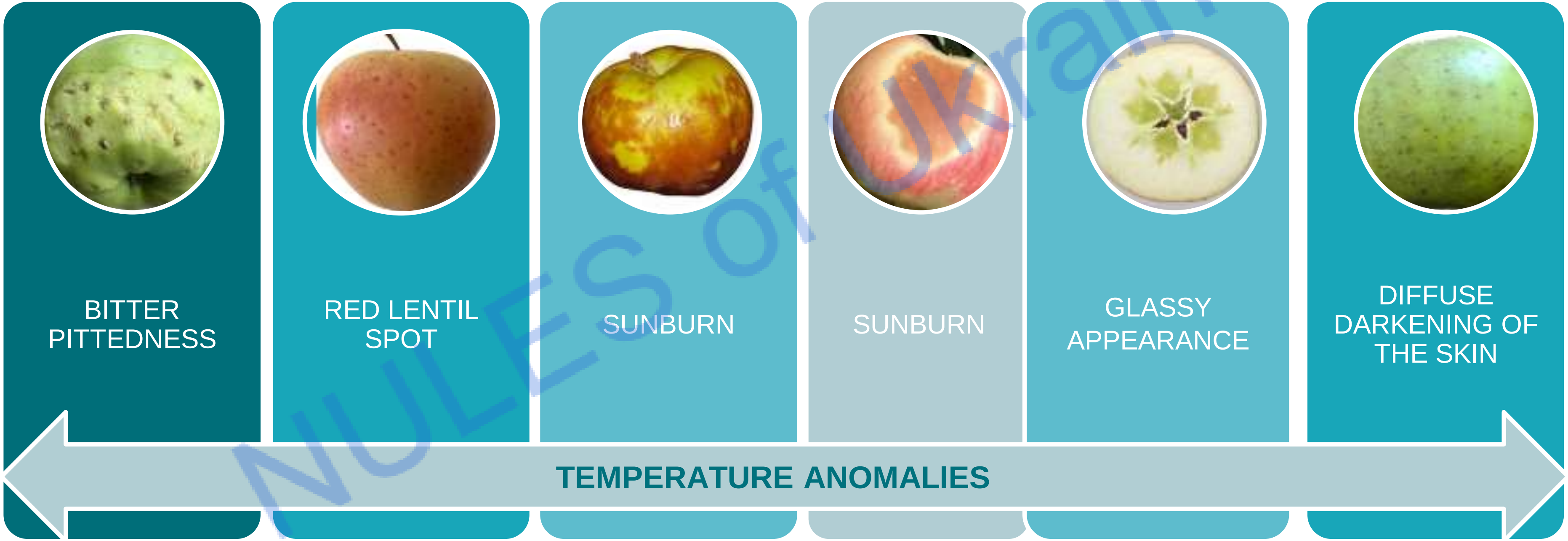
SCAB

STORAGE SCAB

GLASSINESS

SWELLING

EFFECTS OF HIGH HUMIDITY AND RAINFALL


BITTER PITTEDNESS
RED LENTIL SPOT
SUNBURN
SUNBURN
GLASSY APPEARANCE
DIFFUSE DARKENING OF THE SKIN
TEMPERATURE ANOMALIES

ENVIRONMENTALLY SAFE DISINFECTANTS FOR FRUIT STORAGE FACILITIES

- **Ozonation** (after treatment, O_3 breaks down into O_2 within 30 minutes)
  - Concentration for disinfecting chambers: 20–30 ppm; for chambers containing apples: 0.5–2 ppm
- **Hydrogen peroxide with silver** (the peroxide oxidises microorganisms, whilst silver ions have a detrimental effect on bacteria)
  - Solution concentration for chamber disinfection: 8–20 mg/m³; for loaded chambers: 1–2 ml/m³
- **Natural fumigants** (essential oils and extracts) (natural anti-pathogenic agent
  - Tea tree oil – 5–10 mg/l; oregano extract – 10–15 mg/l
- **Anolyte** with pH 6–7 (electrochemical activation of water) (mixture of hypochlorous acid and O_2
  - Active chlorine concentration 200–500 mg/l, dosage 100–200 ml/m²

BIOFUNGICIDES FOR PRE-STORAGE TREATMENT OF APPLES:

- *based on bacteria (genus Bacillus*)
  - Amylo-X (*Bacillus amyloliquefaciens, strain FZB24*)
- based on antagonistic yeasts
  - Boni Protect *(Aureobasidium pullulans)*
- based on antagonistic fungi (Trichoderma)
  - Trianum-P (*Trichoderma harzianum T22*)

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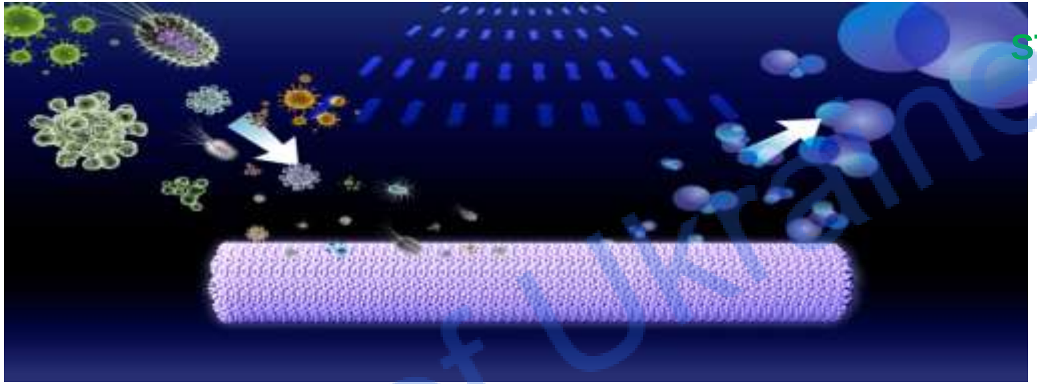
PRE-HARVEST ‘ECO-TREATMENT’ OF APPLE FRUIT

- **Treatment in the orchard 5–10 days before harvest, using SerenadeAmylo-X**
- **Pre-cooling treatment – adding Boni Protect to the cooling water. Maintaining the biofield in storage chambers – ozonation**
- **Treatment with an ethylene inhibitor**

TECHNOLOGIES FOR STORING APPLE FRUIT

Technologies	Controllable factors				
	Temperature, °C	Relative humidity, %	Oxygen content (O_2 , %)	Carbon dioxide content, (CO_2 , %)	Inhibition level C_2 H_4
Normal atmosphere (NA) O_{22} =21%; CO_{22} =0.03%; N=79%	+	+	-	-	-
RA with ultra-low O_2 (ULO) content (0.8–1.2%) and high CO_2 content (0.5–1.5%)	+	+	+	+	+
Dynamic RA (DR) O *content*$_2$ (0.3–0.7%) and CO content$_2$ (0.5–1.3%)	+	+	+	+	++++

SOLUTION FOR SUPERMARKETS

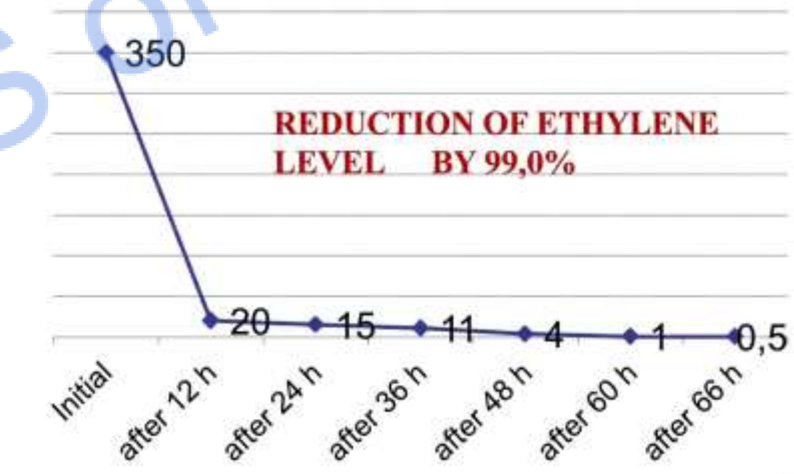


STANDARD COOLED ATMOSPHERE + *AIROCIDE® TECHNOLOGY*

Biotechnology transforms any solid or gaseous organic substance present in the environment into harmless vapour at the molecular level. The size of the object ranges from a few millimetres to fractions of a micron, i.e. smaller than the particles captured by even the best HEPA filters

STORAGE TECHNOLOGY USING AIROCIDE® EQUIPMENT

Ensures continuous removal of ethylene and VOCs, which guarantees the preservation of fruit and vegetable quality in a single storage facility over a long period



GREEN AMMONIA USE IN POST-HARVEST TECHNOLOGIES

as a refrigerant in refrigeration units that cool fruit storage facilities

Advantages over freon

Energy efficiency – has higher cooling capacity compared to freons, lower cooling costs

Environmental friendliness – has zero ozone depletion potential and zero global warming potential

Storage conditions – ammonia systems allow for very precise control of temperature and humidity, which is critical for storing apple fruit

SOLAR PANELS (PHOTOVOLTAICS) ALTERNATIVE SOURCE OF ELECTRICITY IN POST-HARVEST FRUIT PROCESSING COMPLEXES:

- sorting (sorting lines)
- fruit packing (packing lines)
- storage and cooling of apples (compressors, fans, scrubbers)
- charging of machinery, electric forklifts
- apple processing equipment

PRODUCTS MADE FROM APPLES

- TRADITIONAL (apple concentrate), pectin
- TRENDY
  - Functional drinks (freshly squeezed juices, cider, smoothies)
  - Snacks (apple chips, apple pastilles)
  - Raw materials (processing ingredients) for the food industry (apple fibre, purée, as a sugar substitute, varietal concentrates)
  - Zero-waste production (powder – dietary supplement additive)

Eco-packaging made from apple pomace – processing residues used to create biodegradable paper or cardboard.

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RAW MATERIAL REQUIREMENTS

APPLE CONCENTRATE

SRR over 12%,
titrated acids 0.6–0.8%,
degree of starch degradation
7–8 points (variance due to variety characteristics)

PUREE, NATURAL FILLERS

Pectin content over 0.7%, CKI 20–25

CHIPS, SLICES FREEZE-DRIED

SRR over 12%,
TCI 20–25,
flesh firmness 6–8 kg/cm²

low peroxidase activity

THE BEST APPLE VARIETIES FOR ESTABLISHING RAW MATERIAL ORCHARDS:

REMO

RELINDA

REANDA

SCYTHIAN GOLD

REGINDES

REVENA

ARIVA

TOPAZ

FEATURES OF APPLE CONCENTRATE PRODUCTION IN THE CONTEXT OF GLOBAL CLIMATE CHANGE

PREPARATION OF RAW MATERIALS

- Ripe fruit control (overripe apples result in poor-quality concentrate)
- Cooling to prevent the growth of microflora

JUICE EXTRACTION AND PROCESSING

- Enzymatic treatment (if necessary, to break down protopectin)
- Filtration

EVAPORATION

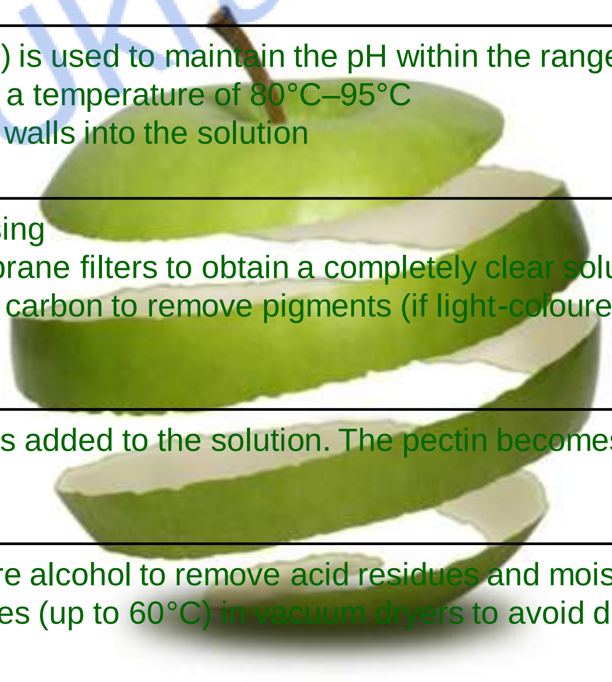
- Low-temperature evaporation
- Aroma capture

ENERGY EFFICIENCY AND RESOURCE CONSERVATION

- Water recirculation (use of water obtained from juice evaporation for cleaning equipment and initial washing of raw materials)
- Energy independence (switch to renewable sources to power the refrigerator and electrical equipment)

PROCESS FLOW CHART FOR THE PRODUCTION OF PECTIN FROM APPLE PULP

Preparation of raw materials	***Grinding***. The raw materials are ground to increase the surface area in contact with the reagent. ***Washing.*** The pomace is washed with cold water to remove residual sugars, colour pigments and soluble acids, which may impair the quality of the pectin ***Blanching.*** Brief heating destroys the pectinesterase enzyme, which can break down the pectin before extraction begins
Hydrolysis-extraction (conversion of protopectin to hydropectin)	***Reagents.*** Hot water with added acids (citric) is used to maintain the pH within the range of 1.5–3.0 ***Parameters***. The process lasts 1–3 hours at a temperature of 80°C–95°C ***Result.*** Pectin is leached from the apple cell walls into the solution
Filtration and purification Separation of the mixture into pectin extract and solid residue	***Coarse purification***. Centrifugation or pressing ***Fine filtration.*** Use of filter presses or membrane filters to obtain a completely clear solution ***Decolourisation.*** Passing through activated carbon to remove pigments (if light-coloured pectin is required)
Precipitation of pectin (extraction from the solution)	***Alcohol method***. Ethyl or isopropyl alcohol is added to the solution. The pectin becomes insoluble and precipitates as a fibrous sediment (gel)
Drying and grinding	**Washing.** The precipitate is washed with pure alcohol to remove acid residues and moisture. **Drying.** This is carried out at low temperatures (up to 60°C) in vacuum dryers to avoid damaging the molecular structure of the pectin. **Grinding to a powder**



ECO-INNOVATIVE MODEL OF SUSTAINABLE PRODUCTION IN THE SECONDARY PROCESSING OF APPLE RAW MATERIALS

1. ELECTRICITY SUPPLY BASED ON RENEWABLE ENERGY

SOLAR COLLECTORS AND HEAT PUMPS	• For preheating water to 50–60 °C
BIOGAS PLANT	• Biomethane obtained through the anaerobic digestion of digestate is burned to generate steam and provide high-temperature heating
PHOTOVOLTAIC PANELS	• Power the centrifuges and pumps and provide lighting

2. ECO-FRIENDLY EXTRACTION (WITHOUT STRONG MINERAL ACIDS)

ORGANIC ACIDS (INSTEAD OF CHLORIDE)	• Malic or citric (biodegradable, less corrosive)
FERMENTATIVE EXTRACTION	• Use of enzymes (cellulases), which allows the process temperature to be lowered and energy consumption reduced
CAVITATION HEATING	• Cavitation breaks down the strong bonds in apple pomace, allowing pectin to dissolve even in pure water or a weakly acidic environment

3. CLOSED-LOOP WATER USE AND GENERATION CYCLE

WASHING OF OILCAKE	• Wastewater treatment via a membrane bioreactor system for reuse
SLUDGE SETTLING	• Use of ethanol, which is regenerated in a rectification column after the process (recovery efficiency up to 95%)
WASTE	• Biogas • Fertiliser • Dietary fibre

WHY VDE IS IMPORTANT IN THE POST-HARVEST PROCESSING CYCLE OF APPLE FRUIT

- Environmental friendliness
- Cost-effective
- Key benefits
  - Low carbon footprint
  - Local sourcing
  - Renewable

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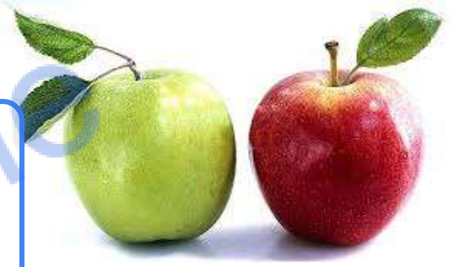

REQUIREMENTS FOR CONTAINERS USED FOR THE HARVESTING, STORAGE AND PACKAGING OF APPLE FRUIT (AND PRODUCTS PROCESSED FROM THEM)

AIR PERMEABILITY

Apples release ethylene and moisture. Eco-tar must provide ventilation to prevent rotting and premature ripening

BIODEGRADABILITY OR RECYCLABILITY

The material must either decompose naturally (composting) or be easily recyclable (e.g. corrugated cardboard)

NO PLASTIC

Complete avoidance of low-density polyethylene and stretch films

FOOD SAFETY

Use of water-based or soy-based inks and adhesives free from harmful solvents

CONTAINERS FOR HARVESTING, STORING AND PACKAGING APPLE FRUIT

Containers for harvesting and storing apples, capacity 200–400 kg

Cardboard boxes (bushes) for packing apple fruit, capacity (12–14) (18–20) kg

Biodegradable bags made from corn starch

FSC (Forest Stewardship Council) certificate

The most important certification for cardboard packaging. It confirms that the wood used for the cardboard comes from forests managed responsibly

- **FSC 100%:** Entirely from certified forests
- **FSC Mix:** A blend of raw materials from certified forests and recycled materials
- **FSC Recycled:** Made exclusively from recycled materials

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ECO-FRIENDLY PACKAGING FOR PROCESSED FOOD PRODUCTS

Biodegradable packaging

Breaks down into natural components during composting

Paper bags with an inner layer of cellulose film or starch-based bioplastic

For apple chips and freeze-dried products

Pouch bags (doy-packs) made from certified compostable plastic

For purées and fillings (small-scale packaging)

Cardboard boxes, corrugated trays and paper tape

Transport packaging

PLA (polylactide) bottles made from corn starch

For concentrate

ECO-FRIENDLY PACKAGING FOR PROCESSED FOOD PRODUCTS

Recyclable packaging

Made from materials that can be recycled many times

Beg-in-box, non-metallised polyethylene

For concentrates, wholesale

Glass bottles

For concentrates

Food-grade metal drums, aluminium tanks

For concentrates, purées

Monopolypropylene bags (code 5)

For crisps, freeze-dried products

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KEY AREAS OF THE STRATEGY FOR POST-HARVEST HANDLING OF APPLE FRUIT IN THE CONTEXT OF GLOBAL CLIMATE CHANGE:

SMART STORAGE (ULO & DCA)

- Enables apple fruit to be kept fresh for up to 12 months without the use of chemical preservatives

ECO-PACKAGING

- Complete elimination of plastic in favour of biodegradable packaging and recycled

ZERO-WASTE PROCESSING

- Production of juices, crisps and concentrates
- Use of pomace to produce pectin, subsequently utilised for biogas, fertiliser, etc.

ENERGY INDEPENDENCE THROUGH RENEWABLE ENERGY SOURCES

- Solar panels: to power refrigeration units and processing equipment.
  Heat pumps: using excess heat from refrigerators to heat office spaces or drying lines

Thank you for your attention!