Organization of Apple (Malus domestica Borkh.) Fruit Drying and Storage Technology in the Conditions of Sirdarya Region

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Abstract: This study is dedicated to the investigation of drying and storage technologies for apple (Malus domestica Borkh.) fruits in the conditions of Sirdarya region. The work analyzes the current state of apple cultivation, the biological and chemical properties of the fruit, and compares the methods of storage in fresh and dried forms. According to the research results, an average of 1.5 tons (15%) of dried product is obtained from 10 tons of fresh apples. The hot and dry climate of the region is favorable for solar drying, which ensures energy efficiency and increases profitability up to 35%. As a result of the study, an effective drying technology suitable for the region and practical recommendations were developed.

Keywords: *apple (Malus domestica), drying technology, Sirdarya region, solar drying, dried apple (dried slices), storage period, economic efficiency, fruit processing, profitability, natural-climatic conditions.*

Introduction

In our country, the cultivation of fruit trees has been developing since ancient times, and among them, the apple (Malus domestica Borkh.) occupies one of the leading positions. The apple stands out not only for its widespread cultivation, but also for its high nutritional value, beneficial properties for human health, and wide possibilities for processing. In various regions of the Republic of Uzbekistan, particularly in Sirdarya region, there are favorable soil and climatic conditions for apple cultivation. The

continental climate of the region, hot and dry summers, abundant sunlight, and irrigation opportunities create great potential for the development of apple orchards and the effective processing of the harvest.

Apple fruits contain high amounts of vitamin C, B-group vitamins, organic acids (mainly malic acid), pectin substances, sugars, and mineral elements (potassium, calcium, iron, and others). These substances improve metabolism in the human body, strengthen immunity, and play an important role in the prevention of cardiovascular diseases and certain types of cancer. Therefore, apples are consumed not only fresh, but are also widely used in industry in the form of juice, puree, jam, canned products, and especially dried products.

The Decree of the President of the Republic of Uzbekistan dated March 29, 2018, No. PF-5388 “On additional measures for the rapid development of fruit and vegetable growing in the Republic of Uzbekistan” and the Resolution dated December 11, 2019, No. PQ-4549 “On additional measures for further development of the fruit and vegetable and viticulture sector and the creation of a value-added chain in the field” set specific tasks for the modernization of fruit and vegetable growing, the introduction of a cluster system, and the development of product storage, processing, and export. Also, the Resolution dated December 15, 2021, No. PQ-52 “On measures to support the fruit and vegetable sector by the state and further development of the cluster and cooperation system in the industry” pays special attention to the integration of growing, storage, processing, and export processes of fruit and vegetable products, strengthening cluster activities, and creating a value-added chain. These documents serve to encourage the deep processing of fruits such as apples, particularly the introduction of drying technologies.

Today, the development of agriculture, providing the population with high-quality and safe food products, and increasing export potential is one of the priority

directions of state policy. As President Shavkat Mirziyoyev noted, the creation of a complete value chain — from the cultivation of agricultural products to their storage and deep processing — is an important factor in the sustainable development of the country's economy. In particular, the development of processing technologies in order to prevent the loss of fruit harvest and create added value has been identified as a pressing task.

Relevance and necessity of the topic:

Currently, the volume of apple cultivation is growing year by year on a global scale. However, apple fruits are a perishable product that is demanding in terms of storage. Due to improper storage or lack of sufficient technologies, a significant part of the harvest is lost. One of the most effective and economically beneficial ways to reduce these losses is the widespread introduction of fruit drying technology. Through drying, it is possible to significantly reduce the moisture content of the product, extend the shelf life from several months to years, reduce transportation costs, and ensure availability on the market throughout the year.

In the conditions of Sirdarya region, the relevance of this topic is even higher. The sharply continental climate of the region — hot and dry summers, abundant sunlight, and low relative humidity — creates very favorable conditions for drying apple fruits using natural and hybrid methods. At the same time, despite the growing volume of apple cultivation in the region, the insufficient modern storage and processing infrastructure leads to the loss of part of the harvest. By improving drying technology, it is possible not only to reduce losses, but also to produce new types of products (dried apple slices, chips, dried apples, etc.), increase export potential, and raise the income of farms.

The large-scale losses arising due to insufficient storage and processing technologies; the availability of opportunities to effectively use the climatic features of Sirdarya region; the need to introduce energy-saving and environmentally friendly

drying methods; the high market demand for dried products and the potential to create added value; compliance with the tasks defined in the Development Strategy of New Uzbekistan for 2022–2026 on intensive development of agriculture, expansion of the processing industry, and increasing farmers' income. Thus, the scientific study of apple fruit drying and storage technology in the conditions of Sirdarya region, analysis of existing methods, and development of effective technological schemes suitable for the region is an urgent and necessary scientific-practical issue of today.

Purpose of the Study:

The main purpose of this graduation qualification work is to scientifically study the technology of drying and storage of apple (Malus domestica Borkh.) fruits in the conditions of Sirdarya region, to analyze existing methods, and to develop effective technological schemes suitable for the region.

Objectives of the Study:

To analyze the importance of apples in the national economy and the state of their cultivation in Sirdarya region;

To study the biological, chemical, and technological properties of apple fruits;

To analyze and compare various technologies for drying apple fruits;

To determine the effect of the drying process on product quality (color, taste, nutritional value) and shelf life;

To substantiate the optimal conditions for storing dried products;

To evaluate the economic efficiency of drying technology;

To develop practical recommendations and technological schemes.

Object of the Study:

Apple (Malus domestica Borkh.) fruits and the processes of their drying and storage.

Subject of the Study:

Technology of drying apple fruits, drying regimes, and their impact on product quality and shelf life.

Practical Significance of the Work:

The recommendations and technological schemes developed based on the research results can be applied by farms, fruit processing enterprises, and clusters in Sirdarya region. This will serve to reduce harvest losses, produce new types of products, manufacture environmentally clean products, and increase farmers' income.

2.3. Methods of Storing Dried Apple Fruits.

Apple (Malus domestica Borkh.) fruits are considered one of the products with high nutritional value and beneficial for human health. Therefore, storing them in various ways for year-round consumption is of great importance. In practice, apple fruits are mainly stored in two ways: fresh and in dried form.

Storing apples in fresh form is a method aimed at preserving the natural state of the fruit to the maximum extent. After harvesting, the fruits are sorted, mechanically damaged ones are separated, and placed under special storage conditions. The optimal conditions for storing fresh apples are a temperature around 0…+2°C and relative humidity of 85–90%. Under such conditions, apple fruits can maintain their quality from 3 months to 6–8 months, depending on the variety. When controlled atmosphere (CA) technology is applied in refrigerated warehouses, the storage period is extended even further.

The advantage of fresh storage is that the fruit retains its natural taste, aroma, and nutritional substances. However, this method also has disadvantages: it requires special cooling equipment, high energy consumption, and in case of improper storage conditions, rotting, drying out, and disease may occur. In addition, the quality indicators of the fruit may decrease during long-term storage.

The storability of apples is determined by their ripening characteristics during

storage. Early-ripening varieties have a short storage period, while late-ripening varieties can be stored for up to 7–8 months. Apples are placed in boxes for storage. Wrapping them in paper improves storability. Paper or wood shavings can also be placed between the apples in the boxes.

The boxes are placed 25–30 cm away from the warehouse walls, with a two-meter passage left between the rows of boxes. One stack should contain 7–8 boxes. There should be 50–60 cm between the top box and the warehouse ceiling. Boxes with apples are arranged in stacks in a checkerboard pattern, three by three and in pairs. Boxes containing fruits of the same variety, grade, quality, and size are stacked together.

It should be noted that insufficiently ripe apples do not ripen at low temperatures; instead, they harden and their taste and aroma remain unchanged. Therefore, it is necessary to adjust the air temperature in the warehouse according to the ripeness of the apples. Cold-resistant apple varieties are stored at -1 to -2°C. Such apples do not store well for long periods at warm temperatures. Varieties such as Pepin Shafran, Kandil Sinap, Renet Simirenko, Golden Delicious, Boyken, Renet Kichunova, Sari Sinap, and Rozmarin are considered cold-resistant. Non-cold-resistant varieties are stored at 2–4°C. Varieties such as Mart, Suvorovets, Aprel, Jonathan, Starking, Antonovka, Renet Shampan, and Ordinary Antonovka belong to the non-cold-resistant group.

The relative humidity during apple storage should be 85–95%. Cooling of the warehouse is achieved by intensively circulating the air until the required storage temperature is reached, with an recommended air flow velocity of 0.2–0.3 m/sec between the stacks.

Managing the gas environment during storage in the warehouse is important. This is particularly effective when storing varieties that are not resistant to low temperatures.

Usually, fruits harvested from the lower branches of the apple tree store better. Therefore, they are picked and stored separately. After harvesting, apples must be delivered to the fruit warehouse within 4–8 hours without delay.

Table 1

Dependence of Apple Quality on Storage Method

Apple Variety	**Storage Method**	**Fruit Quality, %**	
		Standard	**Waste**
Simirenko	Control	89,3	11,7
	Polyethylene bags, containers	100	-
Rozmarin	Control	97,5	2,5
	Polyethylene bags, containers	100	-

Before storing, apples are pre-cooled in special chambers. Every day, 10–15% of the fruit warehouse chamber's capacity is filled with apples. The chamber is fully filled within 7–10 days. The air in the chambers is gradually cooled to 4–6°C, after which it is maintained at the temperature level required for the specific variety.

High-grade and first-grade apples are stored for a long period, while second- and third-grade apples are placed for storage for 2–3 months. They are stored in boxes, cardboard cartons, and containers. Storing fruits in containers ensures more efficient use of the warehouse's 1 m^3 volume. In this case, the density is 250–300 kg per 1 m^3 of usable volume when stored in boxes, and 400 kg when stored in containers.

Placing apples in polyethylene film is widely used in storage. Polyethylene bags with a capacity of 1–3 kg are used for this purpose. Inside these bags, the oxygen content reaches 14–16% and carbon dioxide reaches 5–7% within 1.5–2 months. After placing the polyethylene bags in the warehouse, their openings are left open for two to

three days; once the apples are cooled, the openings are sealed. The polyethylene bags are placed in containers and then stored in the warehouse.

The use of polyethylene containers for apple storage gives good results. Containers that can hold 600–800 kg of fruit are used. Special holes are made in polyethylene containers for controlled atmosphere management.

The variety diversity of apples significantly complicates their storage, as each variety requires a specific storage regime. During the storage period, apples must be regularly inspected. Boxes with apples should be checked once or twice a month. If any defects are found, the fruits are re-sorted.

Dried storage of apples is a method that ensures long-term preservation by reducing the moisture content in the fruit. During the drying process, up to 80–85% of the water evaporates, as a result of which the development of microorganisms stops. When stored under proper conditions, dried apples (qoqi) remain unspoiled for one year or even longer.

The drying technology consists of several stages: sorting and washing the fruits, slicing, pre-treatment to preserve color (for example, holding in salt or lemon solution), smoking, and the drying process itself. Drying is carried out either in the sun or in special dryers. The moisture content of the finished product should not exceed 18–20%.

The main advantages of dried storage are as follows:

The product can be stored for a long time;

Transportation is easy and cheap;

The volume and weight of the product decrease;

Year-round consumption becomes possible.

However, this method also has some disadvantages. During drying, the external appearance of the fruit changes, and some vitamins (especially vitamin C) are

partially lost. In addition, improper drying technology can lead to a decrease in product quality.

2.4. Economic Efficiency of Dried Storage of Apple Fruits in Sirdarya Region.

Drying and storing apple fruits is one of the important and economically effective directions in the processing of agricultural products. This technology provides the opportunity to store perishable products for a long time, reduce losses, and create added value.

When stored fresh, apple fruits suffer a certain amount of losses. During storage, up to 20–30% of the harvest may be lost due to rotting, drying out, and mechanical damage. Drying technology almost completely eliminates these losses, because reducing the moisture content in the product stops the development of microorganisms and allows the product to be stored for a long period.

During the drying process, an average of 10–20% of the finished product is obtained. This indicator varies depending on the variety of the fruit, its composition, and the drying method used. As a result of drying, the volume and weight of the product decrease, which leads to a reduction in transportation and storage costs. At the same time, dried apple products have high added value and are sold at a higher price compared to fresh apples.

The economic efficiency of dried storage is determined by several factors. Firstly, the shelf life of the product increases dramatically. While fresh apples are usually stored for several months, dried products maintain their quality for one year or more. Secondly, the opportunity to sell the product throughout the year emerges, which helps to become independent of seasonal price fluctuations. Thirdly, dried products are export-oriented and enjoy high demand in foreign markets.

However, economic efficiency directly depends on the selling price of the product. If dried apples are sold at a low price, production costs may not be covered.

Therefore, the price of the dried product must be high enough to cover the cost of raw materials and processing expenses. Practice shows that production becomes economically profitable only when the price of dried apples is several times higher than that of fresh apples.

In the conditions of Sirdarya region, the economic efficiency of apple drying and storage technology can be even higher. Because the hot and dry climate of the region allows the widespread use of solar drying methods. This significantly reduces energy costs and lowers the cost price of the product. As a result, farms have the opportunity to produce high-value products with low costs.

The dry continental climate of Sirdarya region and the high level of solar radiation create enormous opportunities for fruit processing, particularly for the introduction of solar drying technology. The “Golden Delicious” variety, selected as the research object, stands out among other varieties with its high dry matter content (14-16%) and dense flesh structure. This guarantees high product yield and quality.

From 10 tons of fresh apple fruits, an average of 1.5 tons of finished product is obtained. According to calculations, total costs amount to 50 million soums, and gross income equals 67.5 million soums. As a result, a net profit of 17.5 million soums is obtained, and the profitability rate reaches 35% (Table 2).

Table 2.

Economic Efficiency of the Solar Drying Method

№	Indicators	Quantity	Price (soums)	Total (soums)
1	Raw material (apples)	10 000 kg	4 000	40 000 000
2	Drying costs (solar)	-	-	5 000 000
3	Packaging and transportation	-	-	5 000 000
4	Total costs			50 000 000

5	Dried product (qoqi)	1 500 kg	-	-
6	Selling price of 1 kg dried apple	-	45 000	-
7	Gross income			67 500 000
8	Net profit			17 500 000
9	Profitability			35%

These indicators clearly demonstrate that the technology of drying and storing apple fruits is economically profitable. Especially considering the rapid perishability of the raw product, creating added value through its processing is of great importance. Through the drying process, the volume of the product decreases, but its market value increases several times. As a result, farms and processing enterprises gain the opportunity to earn high income.

In addition, production costs can be significantly reduced by applying energy-saving technologies. For example, the use of solar energy or the introduction of combined drying methods reduces electricity consumption and increases the overall level of profitability.

Apple Fruit Drying Processes

Drying of apple fruits consists of several sequential technological stages, each of which directly affects the quality of the finished product:

Sorting and cleaning – freshly harvested apple fruits are sorted according to quality, damaged and diseased fruits are separated, and dust and dirt are removed.

Washing – the fruits are washed in clean water to remove external microorganisms.

Slicing – apples are cut into slices of equal thickness, which ensures uniform drying.

Pre-treatment – treatment with ascorbic acid or citric acid solution can be applied to prevent browning.

Drying process – the main stage, in which the fruits are dried in the sun or in special dryers under certain temperature and humidity conditions.

Cooling – the dried product is cooled under natural conditions.

Packaging and storage – the finished product is placed in packaging that meets hygienic requirements and stored in a dry, cool place.

Advantages of Drying Technology

Apple fruit drying has a number of important advantages:

Extends shelf life – while fresh apples can be stored for 1–2 months, dried products can be stored for up to 1 year;

Reduces losses – prevents spoilage and waste of the harvest;

Transportation convenience – transportation costs are reduced due to decreased product weight;

High added value – dried products are sold at a higher price on the market;

Export opportunities – there is high demand for dried fruits in the international market;

Environmental cleanliness – especially in solar drying, no chemical substances are used;

Year-round sales – the product can be sold at any time.

Conclusion

1. In the conditions of Sirdarya region, there are favorable natural and climatic resources for growing intensive and semi-intensive apple varieties and processing their harvest. The continental climate of the region, especially the hot and dry air flow in summer and autumn, allows fruits to be dried using low-cost methods.

2. The nutritional value of apple fruits is determined by the sugars, organic acids, and pectin substances they contain. Strict adherence to technological regimes is required to preserve these substances to the maximum extent during the drying process.

3. Analysis of technological indicators shows that from 10 tons of fresh apples, an average of 1.5 tons (15%) of finished product (dried apples) is obtained. This may vary depending on the variety and dry matter content.

4. The use of solar energy (natural drying) or combined methods significantly reduces electricity consumption. This makes it possible to increase production profitability from 22.7% to 35–43%.

Recommendations

1. Introduce a system of deep processing (drying) of fruits along with selling them fresh in farms of Sirdarya region in order to reduce harvest losses.

2. To reduce production costs and increase product competitiveness, abandon traditional electric ovens and use solar dryers (solar collectors) or combined drying technologies.

3. When storing dried apple products, do not allow the moisture level to exceed 14-16%, and use dry, well-ventilated warehouses protected from pests..

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