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## ANALYSIS OF ECONOMIC INDICATORS OF FOUR DRYING METHODS APPLIED ON THREE APPLE CULTIVARS

Monika G. Kabadzhova<sup>1</sup>, Nikolay N. Dimitrov<sup>2</sup>

<sup>1</sup> Agricultural Academy – Sofia, Institute of Agriculture, 2500, Kyustendil, Bulgaria

<sup>2</sup> Agricultural Academy – Sofia, Institute of Cryobiology and Food Technologies, 1407, Sofia, Bulgaria

\*Corresponding author's Email: [monika.kabadjova@gmail.com](mailto:monika.kabadjova@gmail.com)

### Abstract

Fruits are one of the main components of a healthy diet. They have many benefits and are recommended for regular consumption as part of a varied healthy diet. However, they are seasonal fruits, some need to be processed to ensure more extended storage and consumption throughout the year. The research aims to analyse the economic indicators of three apple cultivars (Golden Delicious, Florina and Freedom) dried by four methods (sun-dried, shade-dried, dehydration, lyophilization). The methodological framework of the study includes: (1) Theoretical overview of apple drying methods; (2) Analysis of the economic indicators of apple drying – gross output, production and additional costs, net income, and rate of return; (3) Determining the benefits and drawbacks of drying apple products. It was found that the drying methods – sun-dried, shade-dried, and lyophilization – have a higher rate of profitability, while dehydration has a lower rate. The lyophilization method is the most profitable for production with Florina, followed by Freedom and Golden Delicious.

**Keywords:** dried apple method, gross output, rate of return, production costs, net income

### INTRODUCTION

As we know, a key element of a healthy diet for everyone is consuming more fruits and vegetables which the World Health Organization recommends (WHO, 2016). Unlike other food groups that humanity consumes, fresh fruit is the only food group that combines maximum health benefits with minimum health risks. Implementing the program for innovative development of agricultural production includes creating technical means and technologies that meet modern requirements.

Solving the problem of the rational use of food sources and their long-term storage is of particular importance in connection with the developing global ecological crisis and the reduction of food raw materials.

Drying fruits is the most ancient way of preserving and keeping them year-round. While

storing fresh fruits, some difficulties arise due to the high moisture content, which is a prerequisite for the development of microorganisms and for the occurrence of enzymatic reactions that lead to a deterioration of their quality. As a consequence, some of the essential benefits of drying fruits are related to human health, the preservation of carbohydrates, vitamins and salts, and the preservation of their organoleptic indicators.

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2) Analysis of the economic indicators of apple drying – gross production, production and additional costs, net income, and rate of return;

3) Determining the benefits and drawbacks of drying apple products.

#### **A theoretical overview of drying apple methods**

Fresh fruit with high water activity is susceptible to heat and decomposes quickly. Air, moisture, light, and temperature cause the development of microorganisms in the fruits, which leads to the deterioration of their taste, smell, colour, and vitamins. Toxins in food have been found to cause several illnesses (Boneva & Ivanova, 2018). In general, fruits are not durable and rugged to store. Therefore, it is necessary to apply preservation and storage methods for a more extended period. One method is drying the produce or the so-called dehydration.

Dehydration is one of the most common methods used to improve the shelf life of fruit and make it easier to transport. In addition, the reduced water content slows down natural decay and the entry of microbes. It was found that different drying methods have an impact on aroma loss, retention, changes and formation in apples, and important parameters are drying time and temperature (Venir, 2010). According to some authors, drying methods used to dehydrate foods must be efficient and economical and also yield high-quality products based on taste, nutrients, colour, rehydration, uniformity, appearance, and texture (Zhang et al., 2017).

Different methods of fruit drying are found in the literature. Sun drying is the most common, and in some studies, an alternative energy source is used - an author's model solar dryer (Georgieva, 2005; Georgiev & Georgieva, 2020), where the drying temperature varies depending on the daily temperatures.

A comparison was also made between drying the fruit using a heat pump dryer at 45°C and the alternative energy source (Georgiev et al, 2017). The advantages of solar drying have been highlighted. Solar drying, which is economical, ensures the preservation of biologically active substances since the fruits

are dried in the shade without direct solar heating (Georgiev et al., 2014).

When drying fruit with hot air, it is essential to determine the temperature range. Most often, it is between 50°C and 90°C. In some studies, the most effective temperature towards increasing quality and saving energy in a hot air dryer was found to be 65°C (Li et al., 2019).

When drying is done by the method of lyophilization, the physicochemical, biochemical, and structural-mechanical properties of the dried fruits affect the duration of drying, which also

includes the following technological stages (Nacheva & Georgieva, 2007):

1) primary drying – the ice crystals formed during freezing sublimate under the influence of initially intense, then moderate pressure, in the conditions of high vacuum;

2) secondary drying – characterized by desorption of residual moisture at positive temperatures in conditions of higher vacuum;

3) end of the process – upon reaching a certain residual moisture of the product, when the vacuum in the sublimation chamber is broken with dry, inert gas, then the product is left for storage.

According to the authors Nacheva & Georgieva (2007), the parameters at which the products are frozen before drying strongly influence their quality in the dried form. As a result, the authors determined with a precise technique the temperature of the final freezing of water in the studied products (eutectic temperature). As a result, the freeze-dried fruits are characterized by minimal moisture (2-5%), high content of carbohydrates, vitamins, mineral salts, maximally preserved enzyme system and excellent organoleptic indicators.

Other technologies developed for fruit drying include infrared drying, microwave drying, radio frequency drying, and hybrid drying methods, combining two or more different techniques (Zhang et al., 2017).

## MATERIALS AND METHODS

In 2023, the cultivars included in the study were Golden Delicious, Florina and Freedom. The three apple cultivars are grown in the experimental plantations of the Institute of Agriculture – Kyustendil. The most common drying cultivar in the research was Golden Delicious (Ergün, 2021; Ghinea et al., 2022; Çetin & Sağlam, 2023).

Four drying methods were included in the exodus: sun-dried, shade-dried, dehydration, and lyophilization (Figure 1). The first three methods were applied at the Institute of Agriculture in Kyustendil and the fourth at the Institute of Cryobiology and Food Technologies – Sofia.

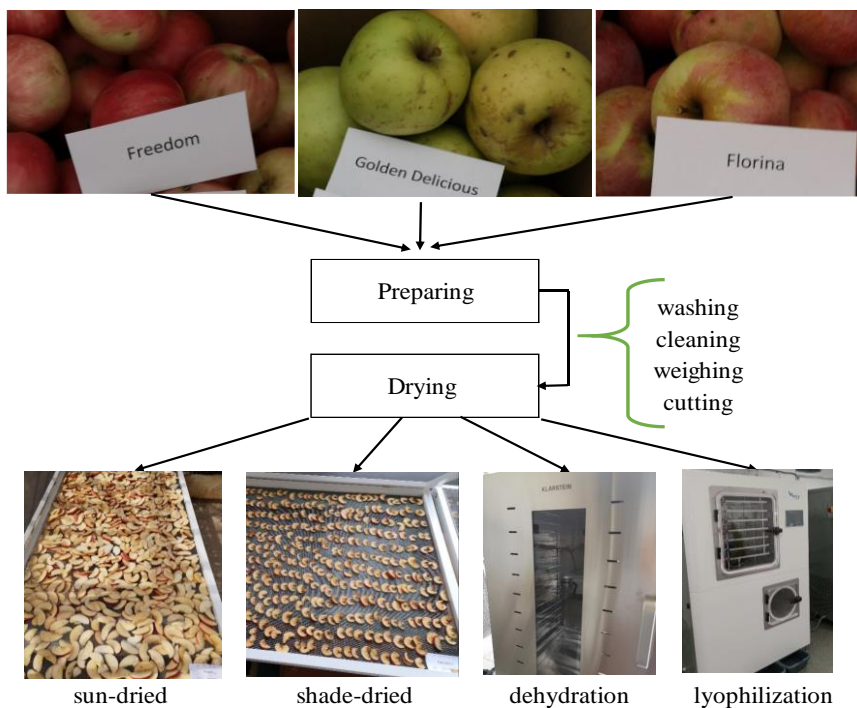
The apples were washed, cleaned, weighed, and cut into slices 0.5-0.7 cm thick for the first three drying methods. Sliced apples were not treated with acid before drying.

In the drying methods – sun-dried and shade-dried, the fruits are dried on nets with frames that are raised 30 cm. The sun and shade

drying temperature depends on the day and night temperatures during the trial period.

The hot air-drying process was carried out on a "Klarstein Master Jerky 16" fruit dryer with a heat output of 1500 W and a uniform heat distribution. The dryer's capacity was up to 20kg, including 16 stainless steel shelves. The apples' drying temperature was 70°C, and the drying time varied depending on each variety.

The process of the fourth type of drying was carried out on a "Hochvakuum-TG - 16.50" lyophilizer. Freeze drying (lyophilization) is a drying process where the water evaporates from the apples after they were frozen. The process takes place in three phases as follows: first phase – freezing of the native product at a temperature of -25°C; second phase – sublimation, removal of water at -25/-35°C under deep vacuum; third phase – desorption (further drying), by heating under deep vacuum, at positive temperatures from +25°C to +35°C. In this method, the apples are washed, cleaned, weighed and cut into 3 cm thick slices. Sliced apples are not treated with acid before drying.



**Figure 1:** Methodology for drying apples.

Source: Author's elaboration

Economic efficiency in agriculture has been studied concerning the cultivation of perennial crops and viticulture (Kopeva et al., 2012), post-harvest technology (Szabó, 2014), farms and cooperatives (Koteva, 2016; Sarov, 2020), dairy cattle farms (Harizanova-Metodieva et al., 2018), evaluation of the economic aspects of urban agriculture (Stoyanova & Koleva, 2020), dried apple pomace (Jaros et al., 2020), financial efficiency of agricultural enterprises (Kirechev, 2021), optimized orchard systems (Zhang et al. 2023) and others.

The measurement of profitability is the most important synthetic measure of the efficiency of economic activity, which expresses the degree of profitability of production, according to Tenev (2014). In this regard, some authors study the economic effect of sustainable apple production, including indicators such as gross output, production costs, net income and rate of profitability (Krishkova & Serbezova, 2018), others do research on the economic evaluation of technological operations in the production of apples, from planting to full fruiting, including taking into account the production factors (Mitkov, 2023), the net returns of apples under natural farming and the conventional chemical based farming (Chandel et al., 2023), the cost of production, the net present value, and the internal rate of return (Chapai et al., 2024). Also, some countries use the managerial-economical software tool “Arbokost”, which calculates the full cost and the cash-flow timeline for fruit growers' farm management (Bravin et al., 2010).

The economic indicators included in the analysis are gross output (BGN/da), production and additional costs (BGN/da), net income (BGN/da) and rate of return (%).

## RESULTS AND DISCUSSION

In 2023, three apple cultivars were selected to be dried and analysed in the

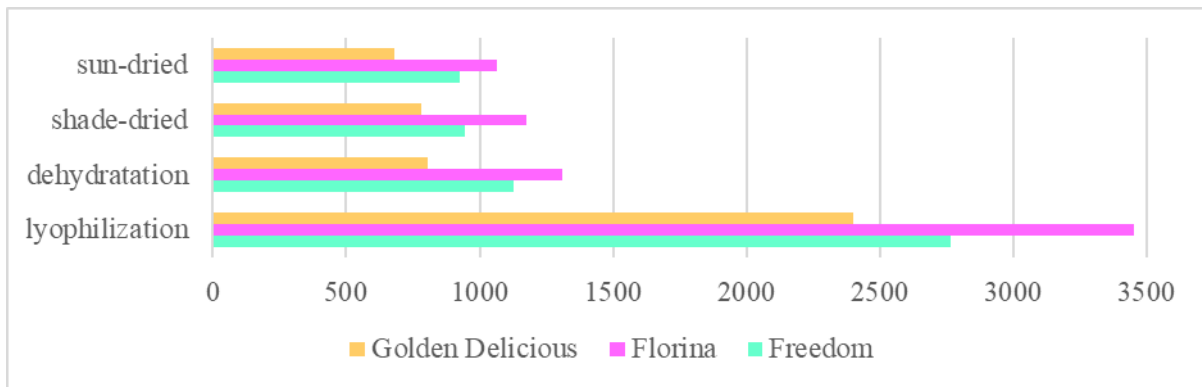
experimental fields of the Institute of Agriculture – Kyustendil.

Care has been taken to grow the fresh apples of the cultivars Golden Delicious, Florina, and Freedom. The cultivar Florina had the highest average production per hectare (261.97 kg/ha), followed by cultivar Freedom (234.5 kg/ha), while the Golden Delicious apple had the lowest yield (168.17 kg/ha). After their harvesting, the fruits were distributed for sun-drying, shade-drying, dehydration, and lyophilization. As a result, the apples were washed, cleaned, weighed, cut, and distributed to the four drying types. After drying, the fruits were weighed again. Based on this, the collected data were processed, and the economic indicators included in the methodology were calculated.

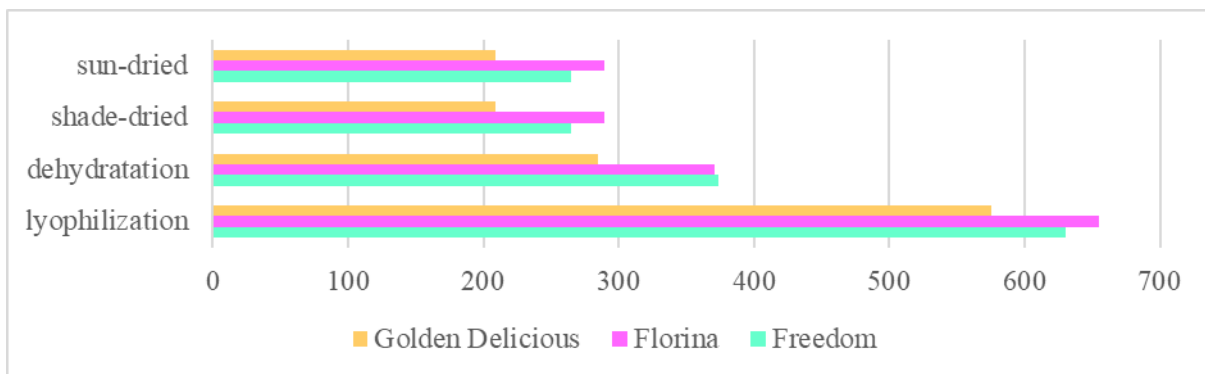
First, the gross output (BGN/da) was calculated, which clarifies the BGN equivalent of the quantities of the dried apples sold (Figure 2). The freeze-dried apples emerge when comparing the individual variants with the highest gross output. The reason is the price of the freeze-dried apples, which is 6-7 times higher than the price of other dried apples – the price is BGN 20/kg for sun-dried and shade-dried, and BGN 25/kg for dehydration. The price for the freeze-dried apples is justified because of the higher cost of this production. In addition, the cultivar Florina performed better than the other two cultivars in lyophilization and other drying types.

Next, the production costs (BGN/da) were calculated, which show us the production's material and labour costs (Figure 3). Again, the production costs had higher results for the freeze-dried apples. The reasons are the same as for the above indicator.

With the lowest production costs, the cultivar Golden Delicious stands out for a lower production in the sun and shade than other dried cultivars. These values are the lowest because there are no additional costs included in either drying method, and the yield in the cultivar is slightly lower than the others.



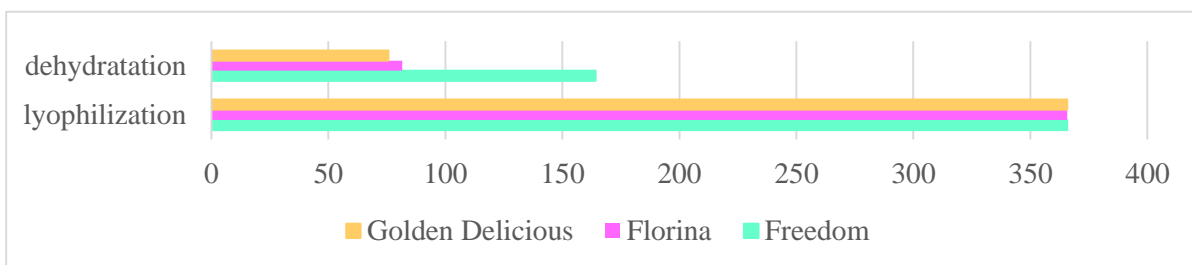
**Figure 2:** Gross output (BGN/da) by drying methods.  
Source: Author's elaboration



**Figure 3:** Production costs (BGN/da) by drying methods.  
Source: Author's elaboration

Also, the additional costs (BGN/da) for each drying method were calculated. They reflect the higher costs incurred in drying the apples between the cultivars. There are the additional costs for the dehydration and lyophilization methods (Figure 4). Economic

calculations indicate that the highest additional cost is incurred for the freeze-dried apples of each of the three cultivars. As with the cultivar Freedom, the increased dehydration costs were observed due to the more extended drying of this cultivar's fruits (drying time).



**Figure 4:** Additional production costs (BGN/da) by drying methods.  
Source: Author's elaboration

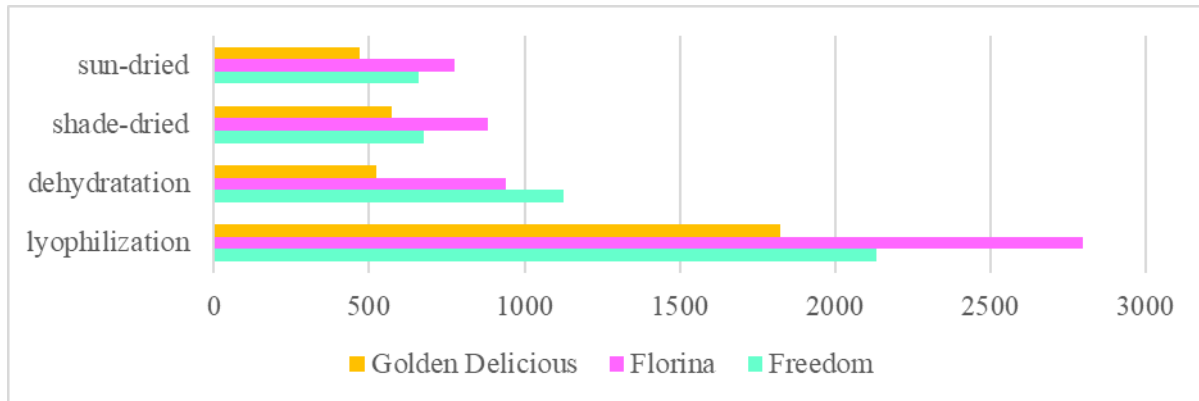
Then, the net income (BGN/da) was calculated, which gives clarity (expresses) on the difference between the income and production cost of the dried apples (Figure 5). Considering the income and expenses for dried

fruits, the freeze-dried fruits stand out here. Relatively, the cultivar Florina had the highest net income, while the sun-dried cultivar Golden Delicious had the lowest. Generally, the dried produce in the dryer weighs less than those in

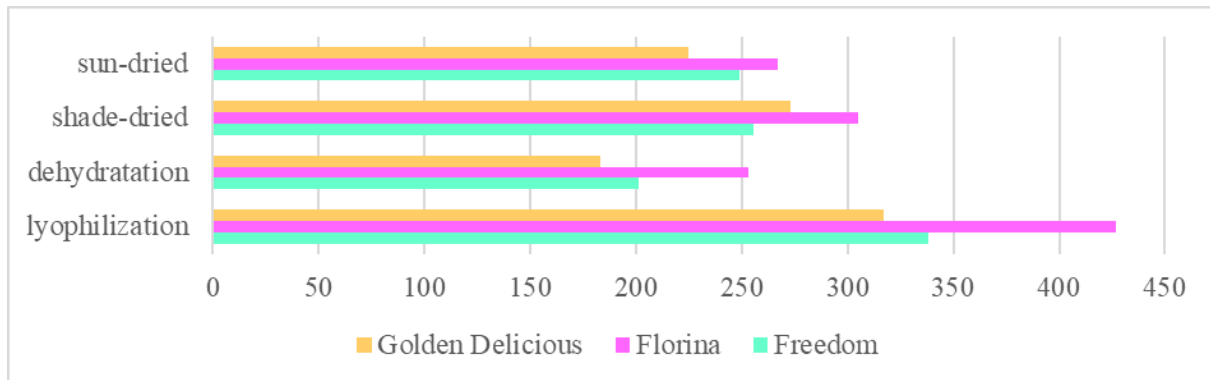
the sun and shade. The fruits with the least weight are the ones from the lyophilizer, but with them, it compensates for the price.

Finally, the rate of return (%) was calculated, which reflects the percentage ratio between the net income and the costs incurred for producing the dried apples. A higher share

of profitability was achieved by the methods – sun-dried, shade-dried and lyophilization, while a lower share was given by the dehydration method (Figure 6). The lyophilization method was the most profitable for production with the cultivar Florina, followed by Freedom and Golden Delicious.



**Figure 5:** Net income (BGN/da) by drying methods.  
Source: Author's elaboration



**Figure 6:** Rate of return (%) by drying methods.  
Source: Author's elaboration

Except for the Florina freeze-dried fruit, the profitability difference between the different drying types was small, so a future study would investigate the consumer preferences for purchasing standard-dried apples and freeze-dried ones.

**Benefits and drawbacks of drying apple products**

The advantages and disadvantages of dried apple production can be met regarding the previous analysis and data collected during the

research period.

Sun-dried and shade-dried apple manufacturing are cost-effective, efficient, and environmentally friendly technologies. One advantage of the dehydration-dried process is its low drying time. Lyophilization is an effective drying procedure that keeps apples fresh for an extended period of time while preserving their format, colour, and size.

The drawbacks of the sun-dried method are extended drying time, which is affected by

weather conditions. The shade-dried method has a much longer drying time than the sun-dried method, which also is affected by weather conditions. In some cases, it is possible to see microorganisms and mould. The following method has a higher electricity cost for the dehydrator as a negative trait. The end method has higher costs for materials and consumables for the lyophilizer.

## CONCLUSION

Fruits, as a key component of a balanced diet, provide several benefits to the human body. They are suggested for frequent intake as part of a diversified healthy diet because the fruit is seasonal, it is processed to ensure long-term preservation and consumption all year round.

Fruits are generally perishable and difficult to keep. As a result, long-term preservation and storage strategies are required. One approach is to dry them, a process known as fruit-dehydration. Drying fruit is one of the oldest preservation methods. It maintains carbs, vitamins, salts, and organoleptic markers, all beneficial to human health. Fruit-dehydration is one of the most prevalent processes used to extend the shelf life of fruits and make them more transportable. Furthermore, the lower water content inhibits natural deterioration and microbial infiltration.

Based on this, four drying methods were used in the study: sun, shade, drier, and lyophilization of three apple cultivars (Golden Delicious, Florina, and Freedom). The following economic indicators were calculated: gross output, production and additional costs, net income, the rate of return, which is the most significant measure of economic activity efficiency and represents the degree of profitability of production.

The cultivar Florina outperformed the other two cultivars regarding lyophilization and other drying types. This type provided the highest profitability despite the greater price and

manufacturing expenses of the freeze-dried apples.

In summary, the sun-dried, shade-dried, and lyophilization methods are more profitable, whereas dehydration is less profitable. The sun and shade-drying methods have an advantage from an ecological point of view. While the dehydration method has an advantage in drying time unlike the other methods. The lyophilization process is the most profitable for growing the cultivar Florina, followed by Freedom and Golden Delicious because the high revenues offset the costs. The share of profitability is directly tied to income, which is a result of the yield.

## ACKNOWLEDGEMENTS

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