Indigestible dietary fiber and astringent compounds of persimmon fruits as an indicator of their suitability for puree

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Abstract. One of the main features of persimmon fruits (Diospyros kaki L.) is too high content of indigestible dietary fiber and astringent compounds, which, in some cases, complicates their processing. When making the puree, coarse fibers are removed at the finisher, but it remains unclear how this affects the quality of the puree output, given there are other features of the persimmon fruit pulp, such as the presence or absence of seeds in it, as well as darkening of color and increasing astringency during heat treatment. Therefore, in this case, an important role can be played by the selection of the best varieties for mashed potatoes and the conditions for its production, which was the purpose of this study. Local persimmon cultivars with varying degrees of pollination - Gosho, Hachiya, Hiakume, were tested. The fruits were first crushed in a grater, then passed through a sieve with a hole diameter of 0.75 mm. It was found that the indicators of suitability for mashed potatoes (the percentage of filamentous fibers, color) deteriorate along with an increase in the number of seeds in the fruit. The puree of fresh fruit and the product of its boiling with the addition of sugar-the candy filling contained more tart leucoanthocyanins and total polyphenols than the puree and candy filling made from frozen (-17°C) persimmons. Thus, the use of unsoiled persimmon fruits can improve the color and increase the yield of puree, and their pre-freezing can reduce its astringency.

1. Introduction
Persimmon (Diospyros kaki L.) is a subtropical tree fruit with worldwide commercial production of 4.6 million metric tons in 2013 [1]. Based on their astringency at harvest and pollination state, these cultivars can be separated into three categories: “astringent,” “non-astringent” and “pollination variant”. All three categories of persimmon can first be harvested when commercial ripe; that is, when the fruit is firm and the skin has changed color from green to yellowish-green, yellow, orange, or reddish-orange (cultivar dependent) [2]. Non-astringent varieties are delicious immediately after harvest. If the fruits are pollinated in the spring and, as a result, have seeds, they will be sweet and delicious immediately after harvest. Non-pollinated (astringent) varieties of cultivated varieties must undergo an additional non-astringency process known as “mellowing” or “bletting” in order to be palatable in raw form.

In 2017, the production of persimmons in Azerbaijan amounted to 200 thousand tons. The main export countries of Azerbaijani persimmon are Moldova, Belarus, Ukraine, Russia, northern regions of Kazakhstan, as well as Arab countries.
The total volume of persimmon exports for 2018 amounted to 114 million dollars. Part of the crop in the amount of about $ 26 million was exported in January-February 2019.

The ripening of persimmons occurs in the autumn months, but due to the lack of industrial processing enterprises, the small-fruited part of the crop remains in the gardens for a long time and spoils on the trees or becomes food for birds. The lack of persimmon processing enterprises is a big problem in the post-harvest sector of the economy.

The question arises, what prevents the successful processing of persimmon fruits?

The experience gained in this case shows that the persimmon fruit is a very difficult object to preserve. For products made using the same technology from different batches of raw materials, the indicators may differ greatly. We take, for example, such an indicator as the concentration of dry soluble substances. Depending on the persimmon variety grown in Azerbaijan and the year of its cultivation, the concentration of dry substances in the cell juice of fruit tissue can vary from 14% to 25 % [3]. This is a very specific raw material, which from year to year greatly changes its chemical and technological characteristics.

Among the components of the chemical composition of persimmons that determine its food - taste properties, an important role is assigned to polyphenols and soluble dietary fibers. Soluble fiber is present in fruits in the amount of 0.54 g/100 g of their raw weight. Insoluble fibers (0.82 g/100 g of their raw weight) are not included in this complex [4].

Indigestible fibers in moderate amounts are useful, as they are able to bind and remove toxic substances from the human body. But in excess, they can lead to serious disorders in the digestive tract. Polyphenols are useful as antioxidants, but their concentration in freshly picked hard persimmons is usually so high that you have to keep it for a week or two until it softens and ceases to be unbearably tart.

During technological processing, the astringency of persimmons increases markedly, especially under the influence of heat treatment [5-6]. All this creates great difficulties in the processing of surplus crops. They try to lead it better, but it turns out to be the same, running in the usual circle. This also applies to getting their persimmon puree, which would be very useful, given that this event could cover the entire small-fruited part of the crop.

In this regard, the purpose of this study was to study the issues related to the selection of cultivars that can provide a high yield of puree, and the conditions for its production, taking into account the possible increase in astringency during further heat treatment.

2. Materials and methods
2.1. Objects of research.
Gosho (does not require pollination), Hachiya (belongs to the intermediate group) and Hiakume (requires pollination) cultivars grown in farms of the Guba-Khachmaz region of the Republic of Azerbaijan were selected as the objects of research.

2.2. Persimmon fruits collection.
The fruits were taken from the trees at the beginning of the last decade of October (Gosho) and in the middle (Hachiya) – end (Hiakume) of November, when they are still very hard, but already completely colored in the color characteristic of this pomological variety.

The average samples were made by removing from three to five trees of the same variety at least 30 pieces of fruit typical in shape, color and degree of maturity of each variety, which were then laid separately in one layer in wooden trays.

2.3. Organization of work.
The analytical part of the work was carried out in the laboratory of Processing and Storage Technologies of the Research Institute of Fruit and Tea Growing.

The fruits were peeled using a small automatic machine LK-PQ25 (Zhengzhou Lankai Machinery Co., Ltd.). The remaining pulp was crushed in a Microplane kitchen grater, and the resulting pulp was
divided into two parts: fibrous and fiber-free using an Endecotts laboratory sieve with a diameter of 0.75 mm through holes.

These three fruit parts were weighed on a ME-T technical scale (METTLER-TOLEDO) with a discreteness of 1 mg - 0.1 g to establish a mass ratio between them.

2.4. Experimental processing.

The resulting fruit parts were subjected to step-by-step extraction: in the first stage-with water heated to 80°C in two stages of 30 minutes each; in the second stage-3 hours heated to a boil with 1.25 % aqueous solution of sulfuric acid; in the third stage-3 hours heated to a boil with 0.9% aqueous solution of sodium hydroxide. The first stage was carried out in order to extract simple sugars, organic acids, and soluble fibers. At the second stage, protopectin and part of the hemicelluloses were transferred to the solution. Step-by-step treatment of the material sample with 1.25 % aqueous solution of sulfuric acid and 0.9 % aqueous solution of sodium hydroxide in accordance with the Henneberg and Stoman's crude fiber determination method according to GOST (State standard of Russia) 31675-2012.

Getting mashed provided for the processing of grated whole fruit without prior purification of the skin. In this case, not three, but two parts were obtained: a tender puree and a fibrous residue. In these two parts and in the candy filling prepared from mashed potatoes, the content of tart compounds was established - water-soluble total polyphenols, as well as alcohol-soluble leucoanthocyanins and catechins. The fruits for making the filling were fresh or from the freezer at a temperature of (- 17°C). The preparation of the filling involved a simple boiling of mashed potatoes with the addition of sugar.

2.5. Chemical analysis.

The content of leucoanthocyanins (flavan-3.4-diols) and catechins (flavan-3-ols) was determined using methods based on the measurement of the optical density of colored extracts [7-8]. The determination of leucoanthocyanins is based on the redness of these compounds when heated with mineral acid. Determination of the total catechin content is based on the reaction of vanillin with fruit catechins.

Determination of the total content of water-soluble polyphenols was carried out by the method based on the titration of 0.1 n. solution of potassium permanganate of the indigocarmine residue, not spent on the oxidation of polyphenolic substances, according to GOST 24027.2-80 and the corresponding article of the State Pharmacopoeia of Russia, which is devoted to the determination of these substances in medicinal raw materials.

2.6. Processing of primary data.

Processing of the results of technological experiments and chemical analyses was carried out using the statistical method of processing experimental data, determining the average values of the calculated value based on at least 5 repeated determinations [9].

3. Theory /calculation

This study focuses on the division of persimmon fruits of different degrees of pollination by processing types based on criteria such as the content of insoluble fibers and tart compounds in the fruit pulp. Before that, they were assigned to different groups only due to intuition and a difference in taste.

4. Results

Many products, such as jams, marmalades, spreads, and toppings, can be made from persimmons using mashed potatoes as a key ingredient. Texture and color are important quality attributes of these products that affect the acceptability to the consumer. The properties of fruit puree depend on the quality and degree of maturity of the fruit used. Changes in the physical, chemical and sensory
properties after harvest and varietal characteristics significantly affect the quality of persimmon puree and its properties as an ingredient.

Persimmon fruits only get their best taste after they are fully ripe after a certain period of aging after harvest.

Visual inspection of freshly harvested varietal persimmons, stored for several weeks at room temperature, showed that the persimmon fruits of different degrees of pollination are not the same in terms of the set of properties that characterize their ability to maintain their original density during post-harvest storage. Under these conditions, the first (after 10 days) begin to soften seedless fruits of the Gosho cultivar (Figure 1), formed from unpainted flowers.

Figure 1. Shape and color of persimmon of different cultivars: A-Gosho; B-Hiakume; C-Hachiya.

As can be seen from Table 1, the fruits of the Hachiya cultivar, which can be formed from both pollinated and non-pollinated varieties (a typical representative of the intermediate group of varieties), remain quite hard for two weeks under the same conditions. And this period is much longer (three and a half weeks) in the Hiakume cultivar, the fruits of which can only be formed from pollinated flowers. In the persimmon of Hachiya involved in this experiment there was one seed in the persimmon Hiakume -2-3 seed.

Table 1. Changes in the consistency and chemical composition of persimmons of the Hachiya and Hiakume cultivars during their post-harvest storage at 18-20° C.

| Date of analysis | Consistence     | Dry soluble substances, °Brix | Titratable acidity, g / 100 g of malic acid | Simple sugars, g/100 g | Monosaccharides | Sucrose | Water-soluble polyphenols, mg/100 g |
|------------------|----------------|-------------------------------|-------------------------------------------|------------------------|----------------|--------|-----------------------------------|
|                  |                |                               |                                           |                        |                |        |                                   |
| 15.10            | Hard           | 25.0                          | 0.38                                      | 12.51                  | 0.16           |        | 247                               |
| 01.11            | Hard-soft      | 22.0                          | 0.47                                      | 14.81                  | 0.20           |        | 130                               |
| 15.11            | Soft           | 22.0                          | 0.50                                      | 16.87                  | 0.46           |        | 80                                |
|                  |                | Hachiya (from the intermediate group of cultivars) |                                    |                        |                |        |                                   |
| 25.10            | Hard           | 19.0                          | 0.37                                      | 12.60                  | 0.78           |        | 197                               |
| 25.11            | Hard-soft      | 17.0                          | 0.32                                      | 13.80                  | 0.47           |        | 100                               |
| 30.11            | Soft           | 17.0                          | 0.30                                      | 14.40                  | 0.30           |        | 70                                |

Average of 5 repeated definitions.

It could be expected that after the collection in the solid state and during the storage of persimmon fruits, the content of dry soluble substances will increase all the time, especially since the content of monosaccharides during the aging process increased all the time. However, this did not happen.

On the contrary, the concentration of substances dissolved in the cell juice decreased at the very beginning of aging. The persimmon juice became more transparent and separated more easily. This is probably due to the fact that along with an increase in the content of simple sugars in the juice (which are not responsible for increasing its turbidity), there was a decrease in the concentration of biocolloids of polyphenolic and pectin nature. Softening may occur as a result of hydrolysis of hemicelluloses, which is indirectly confirmed by the gradually increasing content of monosaccharides.

By the time the fruit pulp softens, the balance between the fibrous part of the pulp changes (the one that, when rubbed, does not pass through the 0.75 mm sieve holes due to its large size) and its fiber-
free parts (the one that passes freely through the holes of this sieve) in the direction of increasing the percentage of the fiber-free part.

Figure 2 shows that in the total mass of ripe softened persimmons, Hiakume (fruits with 2-3 seeds), Hachiya (fruits with 1 seed) and Gosho (seedless fruits), the fiber-free part of the pulp accounts for 55.9, 66.7 and 82.4%, respectively.

![Figure 2. The percentage ratio between the peel, separated with a sharp knife, and the fiber-free and fibrous parts of the pulp from its separation on a sieve with a hole diameter of 0.75 mm in ripe softened persimmons of different varieties: A - Hiakume (fruits with 2-3 seeds); B- Hachiya (fruits with 1 seed); C-Gosho (seedless fruits).](image)

This means that the percentage of the fiber-free part of the pulp is affected by the degree of pollination of the fruit, that is, it depends on the number of seeds in the fruit - the more seeds in the pulp, the lower the yield of its fiber-free part.

Analyses have shown that the dry matter of the fibrous part of the pulp of ripe persimmon Hachiya consists mainly of protopectin (66 %); hemicellulose in it accounts for 4 %, cellulose 4 %, soluble pectin and everything else – 26 %.

![Figure 3. The crude fiber content of ripe persimmon Hachiya in general (1) and in its individual parts: the skin (2), the fibrous part of the pulp (3); the fiber-free part of the pulp (4), g/100 g of raw mass.](image)

Thus, it was proved that the skin of the persimmon fruit and the filamentous fibers that permeate its pulp consist mainly of protopectin.

Figure 3 shows the fiber content of ripe persimmon Hachiya in general and in its individual parts. It shows that the skin and the fibrous part of the pulp of this persimmon contain fiber 7.8 and 3.5 times, respectively, than in the fiber-free part of its pulp.

Figure 4 shows the results of step-by-step extraction of individual parts of ripe persimmon Hachiya with various solvents (first H$_2$O, then 1.25 % aqueous solution of H$_2$SO$_4$ and 0.9 % aqueous solution of NaOH). It shows that the skin and fibrous part of the pulp is dominated by a fraction that can be extracted with a 1.25 % aqueous solution of H$_2$SO$_4$ (76.0 and 64.9 % of their raw mass, respectively). In the fiber-free part of the pulp, the water-soluble fraction prevails – 84.0 % of its raw mass.
As can be seen from figure 5, the proportion of insoluble fiber peel in a total amount of insoluble fiber per one ripe persimmon, and Hachiya equal to 67%, while the shares of insoluble fibers and fibrous bezolovni parts of the flesh are, respectively, 20.6 and 12.4%.

Figure 4. Balance between the different groups of extractive substances of the peel (A), as well as the fibrous (B) and fiber-free (C) parts of the pulp of ripe persimmon Hachiya (% of the raw weight of each of these parts).

Figure 5. The proportion of insoluble fibers of the peel and fibrous and fiber-free parts of the pulp in their total amount in a ripe persimmon Hachiya with a mass of 142.5 grams.

This means that a simple separation on a sieve with a diameter of 0.75 mm through holes can be obtained, a tender puree, in which only 87.6% of the insoluble fibers from the total amount in one ripe persimmon will remain.

Table 2 shows the content of catechins and leucoanthocyanins in the fiber-free and fibrous parts from the separation of ripe softened persimmon Hachiya into two parts on a sieve with a hole diameter of 0.75 mm, and these parts were obtained from both fresh and frozen fruits at (- 17°C).

It shows that the pre-freezing of persimmons increases the yield of the fiber-free part, that is, the tender puree from 66.7% of the total weight of the fruit (direct rubbing without freezing) to 71.4%.

In addition, the fiber-free part from wiping fresh persimmons contains less catechins (50.0 mg / 100 g vs. 90.4 mg / 100 g), and more leucoanthocyanins (14.0 mg/100 g vs. 11.5 mg/100 g) than the fiber-free part obtained from the same persimmon after its preliminary freezing. This is an important factor, given that it is with an increase in the concentration of leucoanthocyanins that the taste of persimmon begins to become more astringency.

Calculations based on the data from this table show that about the fibrous part accounts for about half of the total amount of leucoanthocyanins per whole Hachiya fruit. Therefore, due to its separation, it is possible to reduce the astringency of the fiber-free part, that is, the tender puree.

Quantitative changes in the above-mentioned two groups of substances that could occur during the preparation of mashed candy filling were traced.
Table 2. The content of alcohol-soluble catechins and leucoanthocyanins in the fiber-free and fibrous parts from the separation of ripe softened persimmon Hachiya into two parts on a sieve with a hole diameter of 0.75 mm.

| The name of the part of the persimmon and its share in the initial mass of the whole fruit | Catechins | Leucoanthocyanins |
|---|---|---|
| | Mg/100 g wet weight | Mg / Z g | Mg/100 g wet weight | Mg / Z g |
| Ripe softened persimmon Hachiya | | | | |
| The fiber-free part (95.1 g or 66.7 %) | 50.0 | 47.6 | 14.0 | 13.3 |
| The fibrous part (47.4 g or 33.3 %) | 96.0 | 45.5 | 14.9 | 7.1 |
| Ripe softened persimmon Hachiya after freezing (at -17°C) and defrosting | | | | |
| The fiber-free part (101.7 g or 71.4 %) | 90.4 | 91.9 | 11.5 | 11.7 |
| The fibrous part (40.8 g or 28.6 %) | 78.4 | 32.0 | 14.4 | 5.9 |

The average value of 5 repeated definitions.

Note: Z g is the actual weight of the part of the fruit in grams.

The tested technology of filling for sweets included two stages: 1-obtaining puree from fresh or frozen persimmons; 2-boiling the puree to a dry matter content of 72% in an open boiler with electric heating with the addition of sugar in an amount of 83% and citric acid in an amount of 0.13% to the raw mass of the puree.

Table 3 shows the chemical composition of the chemical composition of both the purees used and the fillings obtained from them.

Table 3. Chemical composition of puree of fresh and frozen Hiakume persimmons and candy fillings obtained from them.

| The product | Dry soluble substances, °Brix | Titrable acidity, g / 100 g of malic acid | Water-soluble polyphenols, mg/100 g | Alcohol-soluble polyphenols, mg/100 g | Vitamin C, mg/100 g |
|---|---|---|---|---|---|
| Puree | 15.0 | 0.60 | 34.0 | 62.8 | 18.1 | 4.17 |
| Filling for sweets | 72.0 | 0.45 | 60.0 | 68.6 | 20.7 | 3.17 |
| Puree | 15.1 | 0.58 | 28.2 | 90.4 | 12.5 | 3.80 |
| Filling for sweets | 72.0 | 0.43 | 48.0 | 100.8 | 15.0 | 3.0 |

It shows that 100 g of fresh persimmon puree and the filling prepared from it contains 62.8 and 68.6 mg of catechins, respectively, and in puree and filling from frozen persimmons, the concentration of catechins is much higher (90.4 and 100.8 mg/100 g).

Catechins are colorless compounds and have a weak astringent taste, so an increase in their concentration in the above-marked boundaries did not significantly affect the color and taste of the puree. It was almost the same as the fresh persimmon puree. However, catechins tend to rapidly oxidize and condense to form polymerized dark-colored products. The more catechins in the puree is, the more its color can darken when kept in the open air, which should be taken into account when working with frozen persimmon puree.

Table 3 shows that 100 g of candy filling made from fresh persimmon puree contains 20.7 mg of leucoanthocyanins (this is more than in the original puree -18.1 mg/100 g) and 60.0 mg of water-soluble polyphenols (this is much more than in the original puree - 34.0 mg/100 g).
From the same table, it can be seen that the filling for sweets made from frozen persimmon puree contains much less water-soluble polyphenols and leucoanthocyanins (48.0 and 15.0 %) than the filling made from fresh persimmon puree (60 and 20.7%). This means that the astringency of the filling for sweets made from frozen persimmon puree is less.

5. Discussion

As can be seen, the performance of the conducted studies is quite high both in terms of raising awareness on the issue of the proper selection of varieties for c mashed into account the sensory properties of this product and its exit from the unit of raw materials and production conditions with mashed into account the possible increase astringency in the process of further heat treatment.

Many foods, such as jams, marmalades, spreads, and toppings, can be made from persimmons using mashed potatoes as a key ingredient. Texture and color are important quality attributes of these products that affect the acceptability to the consumer. The properties of fruit puree depend on the quality and degree of maturity of the fruit used. Changes in the physical, chemical and sensory properties after harvest and varietal characteristics significantly affect the quality of persimmon puree and its properties as an ingredient.

Persimmon fruits only get their best taste after they are fully ripe after a certain period of aging after harvest.

It is established that the yield of mashed potatoes depends on the degree of pollination of fruits, that is, on the presence or absence of seeds in them. The more seeds are contained in the pulp, the darker its color and the lower the percentage of the fiber-free part, that is, the tender puree. As a reference variety, the Gosho variety can be considered, which gives a seedless fruit, in the total mass of which the pulp accounts for 82.4 %.

The study of the balance between different fractions of extractive substances in certain parts of ripe persimmon Hachiya (with one seed) showed that in the fiber-free part of its pulp, the water-soluble fraction accounts for 84.0 % of its total raw mass. The proportion of insoluble fibers of the fiber-free part of the pulp in the total amount of insoluble fibers per ripe persimmon Hachiya was only 12.4 %, so it has a uniform and delicate consistency. In addition, about half of the total amount of tart leucoanthocyanins per whole Hachiya fruit is contained in the fibrous part and peel, which are removed when mashed.

Thus, the production of puree is a promising direction of industrial use of this difficult object of processing.

Freezing persimmons (- 17°C) increases the yield of persimmon puree and reduces the content of tart leucoanthocyanins in the puree and the resulting candy filling.

Cheynier and his colleagues [10] refer to Joslin and Goldstein, according to whom the role of monomeric forms of leucoanthocyanins in giving astringency is not as significant as their di-and oligomeric forms; with such a high content of oligomeric forms of these compounds, as in unripe persimmons, the dry astringent sensation becomes intolerant; when the fruit ripens, the content of polymer forms of polyphenols increases and the astringency decreases.

Rossetti [11] relates the perception of astringent taste to the interaction of polyphenols with cell membrane proteins, epithelial cells, and oral mechano- and chemoreceptors.

According to Suntudprom [12], processing persimmon fruit into the desired product is a difficult task. Especially in conditions where there is not yet sufficient information about how the post-harvest condition of the fruit affects the quality characteristics of this product.

Taking this into account, the researchers focus on modeling new recipe compositions based on mixing persimmons with other biologically active types of fruit raw materials [13]. However, this path has already been tested before, and without success. Developers are expected to use more original technologies with good prospects for commercialization. After all, it is very difficult to make a person love a product again with a familiar texture and taste that he did not like once. The path to success in this business is through non-standard thinking.
6. Conclusion
Thus, this study contains additional information about the chemical and technological properties of pollinated and unpolluted persimmon fruits and methods of their processing in puree, which can help to effectively conduct the processing process with more knowledge of their business.

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