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STORAGE WASTE OF ASPARAGUS AS A VALUABLE SOURCE OF PHENOLIC COMPOUNDS

Summary. Waste from the fruit and vegetable industry dominates on the food waste market. With a tendency of increasing consumers' interest in healthy food and growing consumption of fruits and vegetables, according to forecasts of analysts, the share of this waste will constantly increase. Therefore, nowadays the search for effective solutions of fruit and vegetable waste use, e.g. to obtain biologically active compounds, is extremely timely. Amount of waste during processing and storage of asparagus can reach up to 50%. However, these disposed residuals are rich in polyphenolic compounds, which are characterized by high biological value and can provide additional income. This work provides evaluation of phenolic compounds' content in the waste generated during commercial processing of asparagus, at the stages of preparation for storage and after storage. Two varieties of Asparagus were studied, namely, varieties Prius F1 and Rosalie F1. It was established that the amount of phenolic compounds in asparagus waste reaches 67.73-74.77 mg×100g-1FW depending on the variety. Despite the differences in color, the studied varieties of asparagus did not differ significantly in terms of polyphenolic compounds' total content. In the asparagus waste, content of phenolic compounds was estimated to be only 20-27% lower than in whole spears. Significant differences in the amount of polyphenolic compounds in asparagus waste produced during commercial processing before and after storage were not recorded. Asparagus waste of both studied varieties Prius F1 and Rosalie F1 thus may become a valuable source for obtaining polyphenolic compounds of high biological activity.

Key words: waste, storage, green asparagus, purple asparagus, phenolic compounds.

Introduction. In the "Sustainable Development Goals" adopted by the UN Summit for the period until 2030, goal 12 is set as "Ensure sustainable consumption and production patterns." Task 12.3 envisages halving (per percentage of population) global food waste at the consumer and retail levels by 2030. Food losses occur at all stages from growing, harvesting, processing, storage, logistics and distribution to consumption. The analysis of the food waste market for 2022 shows that fruit and vegetable waste dominates in the share with 20.3% of total food waste. The reasons for such a high amount of waste are losses at the stage of growing products, noncompliance with storage conditions, and disposing of some product quantities during processing. Consumer interest in healthy eating, an indispensable part of which are fruits and vegetables, will fuel the growth of waste in this sector [1].

Losses at a later stage increase the detrimental impact on the global food system. Therefore, reducing losses and waste of fruit and vegetable products can be one of the leading global strategies for achieving sustainable food security and improving diets, reducing greenhouse gas emissions and wasted resources, as well as increasing productivity and ensuring economic growth.

Fruit and vegetable waste can be used in various industries. Most often, waste from the fruit and vegetable industry is composted and used as organic fertilizer to improve the soil properties. In addition, such waste can be used in animal feed. Today, the possibilities of using waste to obtain biofuel, biogas or other forms of energy through anaerobic fermentation or pyrolysis are also being studied. However, content of antioxidants, phenolic compounds and other phytonutrients that fruits and vegetables are rich in, can be still high in the fruit and vegetable waste. Therefore, it can be a promising raw material for obtaining valuable compounds with high biological activity, thus creating products with value added.

Recent research and publications analysis. Phenolic compounds are of particular importance in fruit and vegetable waste. Today, residues and byproducts of the food production chain are used to extract phenolic substances as products with high value added [2]. Phenolic substances show high biological activity. For instance, they serve as protective compounds during cardiovascular diseases, cancer, diabetes, inflammation, etc. [3]. Their impact on health is known especially due to their strong antioxidant effect. These compounds are classified into several groups, such as phenolic acids, flavonoids, xanthones, stilbenes, lignins, tannins, and others, being also divided into various subgroups.

Depending on the type of fruit or vegetable, content of phenolic compounds differs, with presence or even prevalence of specific groups. Asparagus contains a wide range of phenolic substances, therefore, the use of waste obtained during its processing for the production of biologically active compounds is considered today as a valorization strategy [4].

Asparagus waste reaches up approximately 50% of the total harvested amount [5]. Most waste is generated during canning of asparagus. Only 15 cm of the tops of asparagus spears are left for canning, and the remaining 15-18 cm ends up in the waste. At least 20% is wasted during its commercial processing, storage and further preparation. Such a large proportion of waste derives from removing the lower part of asparagus spears (usually about 2 cm) during the storage, as this piece tends to be coarser or due to the necessity of adjustment spears to same length. Such slicing is, however, recommended to reduce mass loss during storage, with preference of the straight cut to diagonal to reduce surface of evaporation from the fresh cut [6]. In addition, after storage, asparagus slices are renewed by removing the dried part of the spear. Unfortunately, due to this fact the basal part of asparagus spears that actually contains a greater number of biologically active compounds is removed [7].

According to literature, Asparagus contains variety of phenolic acids: gallic, protocatechuic, *p*-hydroxybenzoic, vanilic, caffeic, chlorogenic, *p* – coumaric, ferulic, sinapic. Among flavonoids, rutin, isoquercetin, hyperoside, astragalin, quercetin and kaempferol are abundant [8]. Rutin dominates among phenolic substances, with the share of about 67%. Further 10% are taken by its derivative – rutin-4'-glucoside [9]. Recent studies indicate that asparagus waste can be an excellent source for the natural rutin production [10]. In addition, asparagus contains stilbene, lignans and norlignans [11]. Still, the content of phenolic compounds and their ratio differs a lot depending on such factors as genotype, variety, agricultural cultivation techniques, stage of plant development, soil composition, environmental conditions and other abiotic and biotic factors during plant growth, as well as storage conditions of the harvested product [12-14].

Purpose statement. In view of the abovementioned, this work aims to evaluate the content of phenolic compounds in the waste generated at the stages of asparagus commercial processing of asparagus, during preparation for storage and after storage.

Materials and methods of research. For this study two varieties of asparagus (Asparagus officinalis L.) were chosen: the green variety Prius F1 and the purple-green variety Rosalie F1. Plants were harvested at the end of the season (the third decade of June) in 2023 in the Chaichyntsi village, Ternopil region, Ukraine. After collection, the samples were immediately cooled and transported to the laboratory of the Institute of Food Resources (Kyiv), where all further research was carried out. Asparagus had closed bracts and no visible mechanical damage, as well as met the size standards: diameter at least 8 mm, length 23-25 cm, as corresponds to the CODEX STAN 225-2001 standard. The prepared asparagus was stored at a temperature of 2°C±0.5 and a relative humidity of 95%±1 for 14 days.

The total content of polyphenolic compounds in mg per 100 g of raw weight was determined using the Folin-Denis reagent, according to National Standard of Ukraine 4373 [15]. This determination method is based on the complexation reaction of polyphenols with the Folin-Denis reagent that form colored substances. Reaction is followed by the determination of the optical density of the solution (measurements were made at a wavelength of 670 nm). The amount of polyphenols was determined by the extinction coefficient of rutin.

The content of polyphenolic compounds was determined in the following samples:

1. Whole asparagus spears, without separating the basal part prior to storage. Different asparagus variates were marked as Prius 1 and Rosalie 1, respectively.

2. Waste in preparation for storage – Prius 2 and Rosalie 2.

3. Whole asparagus spears after storage before the separation of the basal part – Prius 3 and Rosalie 3.

4. Waste, produced during preparation for product sale after storage – Prius 4 and Rosalie 4.

The research was carried out in five repetitions, and the results were subjected to statistical processing by the method of variance analysis.

Results and discussion.

During preparation for storage or sale, operations of primary processing of asparagus spears are carried out, when the lower section of asparagus is leveled and the spears are collected in bundles of standard height. On this stage, first asparagus waste is produced (Fig. 1).

a – place of an oblique cut to be leveled; b – asparagus leftovers accumulated during preparation for storage; c – asparagus prepared for storage; d – basal part of asparagus after storage to be cut off due to its condition.

Fig. 1. The asparagus waste production

In addition, more waste is formed at the stage of commercial processing after storage, when the lower part of the dried slices is removed.

According to our observations, at the stage of primary processing, 15-17% of stems are sent to the waste, depending on the varietal characteristics and quality characteristics. After storage, when renewing the slices, another 5 to 7% of asparagus is thrown away.

When analyzing the content of polyphenols in samples of whole asparagus before storage, no significant differences were recorded for different varieties (Fig. 2).

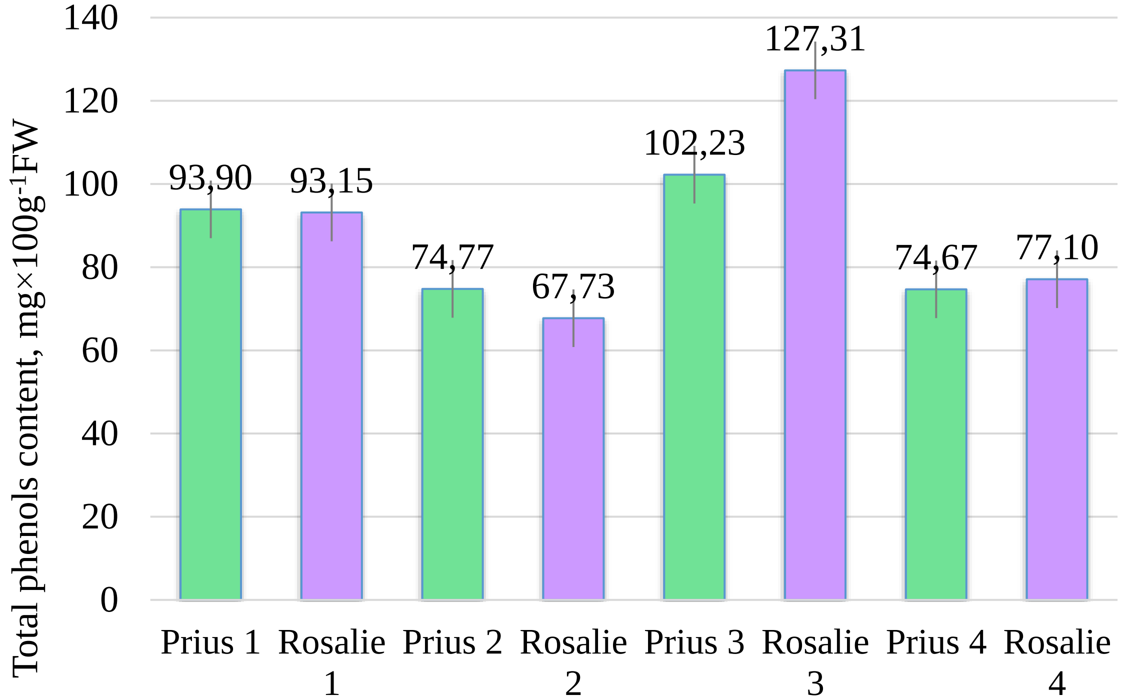

Fig 2. Total content of phenolic compounds in different asparagus samples

As can be seen from the histogram, after storage of asparagus, the content of phenolic compounds significantly increased in whole asparagus shoots of both varieties (samples 3 vs samples 1). However, if the Prius variety showed an increase in phenolic compounds of only about 9%, the Rosalie variety showed an increase of 36%. In literature, different data and opinions regarding the change in the amount of phenolic compounds during storage of asparagus are presented. It was described that the phenolic content of asparagus increases during the first days of storage at 4 °C and remains stable thereafter [16]. Toscano et al. showed that the total content of phenolic compounds increases in Atlas asparagus variety on the third day of storage, and then gradually decreases [17]. The authors believe that this decrease in the total level of phenolic compounds reflects a response to the aging of asparagus.

Barberis et al. observed a similar pattern of changes in the total phenol content during storage of Vegalim asparagus variety [18]. This variety showed an increase in the amount of phenols on the 6th day, however, on the 12th day of storage, the content of polyphenols decreased by 20% from the initial content. Two other varieties described in this article showed a completely different trend of changes in the content of polyphenols. Grande (green) and Purple Passion (purple) asparagus after 12 days of storage increased the content of polyphenols by 45 and 36%, respectively.

A constant increase in polyphenolic compounds was described in asparagus of the Grande variety stored at 2 °C and 10 °C by Palma et al. [19]. Authors explain the growth trend by an increase in the content of phenols in the cell walls of asparagus. However, the authors note that spears stored at 10 °C showed no change in phenolic content when they were in the stage of decay, most likely because decaying cells are no longer able to synthesize phenolic compounds. The opposite nature of the change in the content of phenolic compounds was observed by Chinese researchers. They showed that with increasing storage time, the amount of phenolic compounds decreases [20]. As noted by these authors, this may be due to the constant involvement of phenols in the synthesis of lignin during storage, since phenolic compounds serve as precursors of lignin synthesis.

Such radically different results prove that not only the quantitative characteristics are different in different asparagus varieties, but also the nature of the formation and degradation of polyphenolic compounds can differ significantly depending on the varietal specificity and other factors.

As for the basal parts of asparagus spears, which are normally disposed (samples 2 and 4), we observed them containing a 20-27% lower amount of phenolic compounds than in whole spears. However, such amount of phenolic compounds in such waste is still quite high: 74.77 $mg \times 100g^{-1}FW$ in the Prius variety and 67.73 $mg \times 100g^{-1}FW$ in the Rosalie variety. Similar results were obtained by other authors [20], although Rodríguez et al. claim the basal part of asparagus to be richest in polyphenolic compounds [8].

We did not record significant differences in the basal parts of asparagus, which are waste before and after storage. It is obvious that some changes, however, occur anyway as long as physiological processes are taking place. But, perhaps, in parallel with the new formation of polyphenols, process of their degradation occurs with comparable speed, therefore detected sum of polyphenolic compounds is not reflected. Differences still might be traced in the content of individual phenolic substances, but to detect such, additional research is required.

Conclusions. According to our data, asparagus waste of both studied varieties, Prius and Rosalie, contains high amounts of phenolic compounds and can thus become a valuable source for obtaining compounds of high biological activity. Significant differences in the amount of polyphenolic compounds in asparagus waste produced during commercial processing before and after storage were not recorded. Despite the differences in color, the studied varieties of asparagus did not differ noticeably in terms of the total content of polyphenolic compounds. Variety-specific features also did not affect the amount of phenolic compounds in asparagus waste. Additional research is needed to identify the transformation of individual phenolic substances in waste samples obtained before and after storage.

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ВІДХОДИ ПРИ ЗБЕРІГАННІ СПАРЖІ ЯК ЦІННЕ ДЖЕРЕЛО ФЕНОЛЬНИХ РЕЧОВИН

Анотація

Відходи плодоовочевої галузі займають переважаючу частку ринку харчових відходів. Враховуючи тенденцію до зацікавленості споживачів у здоровому харчуванні та зростання споживання плодів та овочів, за прогнозами аналітиків, частка цих відходів буде постійно зростати. Тож актуальним є пошук ефективних рішень для використання плодоовочевих відходів для отримання біологічно активних сполук. Відходи при переробці та зберіганні спаржі можуть сягати до 50 %. Найчастіше відходи компостують та використовують у годівлі тварин. Однак, відходи плодоовочевої продукції містять цінні фітонутрієнти на які багаті плоди та овочі. Тож вони можуть бути перспективною сировиною для отримання цінних сполук з високою біологічною активністю та створення продукції з доданою вартістю. Спаржа містить такі фенольні кислоти, флавоноїди інші речовини фенольної природи, що володіють антиоксидантними, антибактеріальними, вітамінними властивостями. Очевидно, що і відходи спаржі багаті на поліфенольні сполуки, що характеризуються високою біологічною цінністю і можуть давати додатковий прибуток. У роботі оцінили вміст фенольних сполук у відходах, що утворюються під час товарної обробки спаржі, на етапах підготовки до зберігання та після зберігання. Досліджували спаржу сортів Пріус F1 та Розалі F1. Незважаючи на відмінності у забарвленні, досліджувані сорти спаржі за сумою поліфенольних сполук достовірно не відрізнялись. У відходах спаржі на 20-27% нижча кількість фенольних сполук, ніж в цілих списах. Встановлено, що сума фенольних сполук у відходах спаржі сягає 67,73-74,77 mg×100g-1FW залежно від сорту. Суттєвих відмінностей у сумі поліфенольних сполук у відходах спаржі, що утворюються при товарній обробці до та після зберігання не зафіксовано. Відходи спаржі обох досліджуваних сортів Пріус F1 та Розалі F1 можуть стати хорошим джерелом для отримання поліфенольних сполук високої біологічної активності.

***Ключові слова*:** плодоовочева продукція**,** відходи, зберігання, спаржа зелена, спаржа фіолетова, фенольні речовини.