UDC: 664.002.8

PROSPECTS FOR PROCESSING AND USE OF ROOT VEGETABLE WASTE IN FOOD PRODUCTION

M. Samilyk, PhD, associate professor
N. Bolgova, associate professor
R. Tsyrulyk, graduate studentTechnology and food safety department
Sumy National Agrarian University
160, Herasyma Kondratieva str., Sumy, Ukraine, 40021
T. Ryzhkova, doctor of Technical Sciences, Professor
Department of Processing Technology and Standardization of Livestock Products
Kharkiv State Zooveterinary Academy, 1, Akademichna str., Mala Danylivka, Dergachivsky dist., Kharkiv reg., Ukraine, 62341

DOI: https://doi.org/ 10.15673/fst.v15i4.2253

Article history

Received 22.06.2021
Reviewed 12.08.2021
Revised 25.09.2021
Approved 01.12.2021

Correspondence:

M. Samilyk
E-mail: maryna.samilyk@snau.edu.ua

Cite as Vancouver style citation

Samilyk M, Bolgova N, Tsyrulyk R, Ryzhkova T. Prospects for processing and use of root vegetable waste in food production. Food science and technology. 2021;15(4):60-68. DOI: https:// 10.15673/fst.v15i4.2253

Цитування згідно ДСТУ 8302:2015

Prospects for processing and use of root vegetable waste in food production / Samilyk M. al.// Food science and technology. 2021. Vol. 15, Issue 4. P. 60-68. DOI: https://doi.org/ 10.15673/fst.v15i4.2253

Annotation. The aim of this study is substantiation of expediency for processing waste products of root vegetables (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) into functional food additives. The structure of vegetable powders and their content of elements (in % on dry matter) has been analyzed in the article. Experimental samples were made from the main (edible) part of root vegetables and their peels. To make powders, at first chopped vegetables and their peels were dried in infrared dryers during 3 hours at a temperature of 45–50°C to a mass moisture share of 8–10%. The dried particles were milled in a laboratory mill LZM-1 (shaft rotation speed 1047 rad/s) to a size providing full passage of the material through a sieve №015 (δ>100). The structure of vegetable powders was studied by electron microscopy. It was found that all vegetable powders have a crystalline porous structure and, accordingly, hydrophilic properties which enable their use in food production as structure stabilizers, emulsifiers and moisture retainers. The study of the content of some minerals in the samples were performed using detector SEM and EDS based on a microscope. It was found that vegetable powders contain essential macro-elements (K, Na, Ca, P, Cl, S, N), irreplaceable micro-elements (Fe, Mg) and conditionally vital micro-element Si, which was found only in a powder made from *Apium graveolens* peels. The study showed that *Beta vulgaris* powders are rich in iron (2.16% is contained in edible root and 1.08% in the peel). The powder made from *Daucus* peel contains more potassium (31.38%) than the powder made from the main part of the vegetable (27.1%). Te powders made from *Apium graveolens* peels contain the highest amount of iron (5.49%) compared to other vegetable powders. The powder made from *Pastináca sátiva* peels is inferior to the main part of the vegetable by mass ratio of macro- and microelements. The only exceptions are calcium, which is found only in the peels (6.12%) and iron (1.27% against 0.6% in the main part of the vegetable). *Pastináca sátiva* peel contains the highest amount of magnesium (0.87%) compared to other root vegetables. These results affirm the expediency of processing root vegetable waste (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) into food additives for functional purposes.

Key words: *Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*, vegetable peels, food additives for functional purposes, drying.

Introduction. Formulation of the problem

Vegetables are known to be main source of vitamins, folades, amino acids, carotenoids, bioflavonoids and dietary fiber. They are combined with different products of animal origin to increase biological value and add certain functional properties. Vegetables are eaten raw and canned. They are the main and auxiliary raw materials for production of many food products.

During vegetable processing a large number of secondary resources are formed. Vegetable by-products are secondary products which are often thrown away during production or other stages of food processing [1]. Secondary products are the source of organic and microbial contamination of ecosystem. During waste disposal by thermal method significant emissions of pollutants are thrown into atmosphere and drain water. With their accumulation and rotting occurs the breaking of ecological balance due to active propagation of microorganisms.

That is why fruit and vegetable waste is not suitable for long-term storage, it requires immediate processing, disposal or tinning. The problem of their processing, without exaggeration, should be considered global as the number of such waste is constantly growing.

Food industry is one of the most wasteful sectors of economy. In terms of waste generation, it is inferior only to extractive industries [2]. The reason of waste generation is the use of imperfect processing technologies and lack of proper logistics. About 45% of vegetables and products of their processing are thrown away worldwide [3].

However, vegetable waste can be additional source of nutrients, so the study of their composition and properties is an issue of extremely importance.

Analysis of recent research and publications

During the processing of plant raw materials, by-products such as peels, seeds, marc, pulp, mill cake and others are formed [4]. However, they are not used in the production process and are classified as waste. Accumulation of waste in dumps not only worsens the state of environment, but also leads to a shortage of natural resources due to irrational use of raw materials [5]. Nowadays, the fruit and vegetable industry produces 500 million tons of peel residues, which makes from 3 to 50% of total fresh mass of fruit or vegetables [6,7].

It is known that vegetable waste contains a lot of fiber and biologically active compounds, including polyphenols, antioxidant compounds and vitamins. They are an inexpensive source of bioactive compounds and vitamins.

The authors [8] showed that application of vegetable powders in bakery products will increase the content of vitamins and minerals in them and improve organoleptic properties of products. This makes it possible to introduce them into food in order to ensure nutraceutical functionality [8]. In addition, vegetable residues are included in the "green list", they are considered to be non-infectious and recyclable [9, 10].

It was found that some types of vegetable peels have strong antioxidant properties [11] and are a source of dietary fiber. They can be used as an effective functional ingredient for development of bakery products enriched with fiber [12]. There are studies concerning the use of potato peels as a functional ingredient in the production of pastry and bakery products to increase nutritional and biological value [13, 14]. The studies of many scientists show that carrot pomace has a positive effect on organoleptic and physic and chemical parameters of flour products [15, 16].

It has been proved that stability and functional properties of plant raw materials before their use are best maintained in a form of powder [17]. Nowadays, vegetable powders made from vegetables and derivatives of their processing are widely used in the food industry as food additives for functional purposes. Prebiotic plant powders contain large amount of fiber, for example, 95% of beet pulp consists of dietary fiber [18]. There are studies concerning possibility of using vegetable powders in the production of confectionery, dairy, bakery, pasta and other products not only for enriching them with functional ingredients, but also for providing new technological properties. Powders are able to improve structural and mechanical properties of dough and appearance of finished products. Antioxidant properties of vegetables remain after heat treatment. It was found that powders obtained from fruits and vegetables with a dispersion up to 0.25 mm have antioxidant and prebiotic properties. They contain phyto-estrogens and folades, which are a natural form of vitamin B9 [19]. In addition, vegetable powders are classified as phytoestrogenic, as isoflavones and quercetin, which are part of most vegetables, are antioxidants [20].

Spinach, potato, banana, nettle and carrot-celery powders contain a large amount of folades and belong to the group of folade-containing [21]. The study [22] presents classification of plant powders according to their functional properties. According to proposed classification the powders are divided into 4 groups (antioxidant, prebiotic, phyto-estrogenic, folade-containing). Antioxidant powders retain maximal amount of carotenoids, vitamins C and E. Prebiotics selectively stimulate growth and activity of one or more bacteria species in a large intestine.

A number of authors point out the expediency of using cryopowders for therapeutic and prophylactic nutrition of people of different ages [23]. Technology of processing waste from juice production, apple, citrus, grape pomace and beet pulp into functional cryopowders and their use as pectin-containing additives has been developed [24]..

Analysis of scientific research has shown that vegetable powders have functional properties and can be used as food additives in various sectors of food industry. As raw materials for production of vegetable powders, it is advisable to use root vegetables growing well in Ukrainian climate and are widely used in food and culinary products: *Beta vulgaris*, *Daucus*, *Apium graveolens*, *Pastináca sátiva*. *Beta vulgaris* – is a useful vegetable that is grown and processed in many countries around the world. *Beta vulgaris* has high antioxidant properties, contains sugars, dietary fiber, phenolic acids, can be used as a natural colorant [26]. *Daucus* is a source of carotenoids, 95% of which are carotenes. 35% of carotenoids in dried carrots are converted into vitamin A [27]. *Apium graveolens* contains calcium, phosphorus, magnesium, potassium, zinc and iron, as well as vitamins A, E, C and vitamins of B-group [28]. The white roots of *Pastináca sátiva* contain vitamins: carotene - 0.02 mg/100g, B1-0.08, B2-0.13, C – from 9.3 to 30, PP – 0.94, B6 – 0.11 mg/100 g [29].

Food additives for technological purposes can be introduced into raw materials and food products at different stages of their production. Vegetable powders can be used as a variety of food additives as they have properties characteristic for different functional classes. Recently, natural colorants have become especially popular in food industry as an alternative to synthetic ones [30]. Carotenoids are mainly responsible for yellow and orange colors [31], betalains form purple and yellow pigmentation color [32]. Functional and structural characteristics of color carrot pigments make it a good raw material for getting natural colorants with practical application in food industry, especially in foods with low pH, beverages and confectionery [33]. In *Beta vulgaris*, are found betacyanins, which are responsible for bright red color, are soluble in water and sensitive to prolonged heating [34]. Pigmental compounds also contribute to overall antioxidant ability depending on amount and the compound [35]. Moisture-retaining and stabilizing ability of powders in the production of sour milk drinks has been affirmed [36, 37]. Functional properties (moisture-retaining ability, emulsion ability, emulsion stability, oil binding ability) of dried vegetables have been affirmed [38]. Vegetable powders can be used as antioxidant-rich flavor enhancers for bakeries [39], confectionery [40] and sweets [41]. In addition, vegetable powders are used for improvement of nutritional value of beverages, as aromatizers and natural colorants [42].

Taking into account the above mentioned, we can state that production of powders from root vegetables and their peels is expedient. However, there are no studies concerning content of micro- and macroelements in peels of some vegetables of regional importance (*Beta vulgaris, Daucus, Apium graveolens (rapaceum), Pastináca sátiva*). Such study will allow to substantiate the need for processing vegetable peels into powders and suggest ways of their using in food production.

The **purpose** of this study is substantiation of expediency for processing waste products of root vegetables (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) into functional food additives. For achieving this goal, the following research **objectives** have been developed:

– analyze microstructure of vegetable powders made from main part of root vegetables and their peels;

– investigate and compare mass content of micro- and macro-elements in powders of root vegetables *(Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva)* and their peels.

Research materials and methods

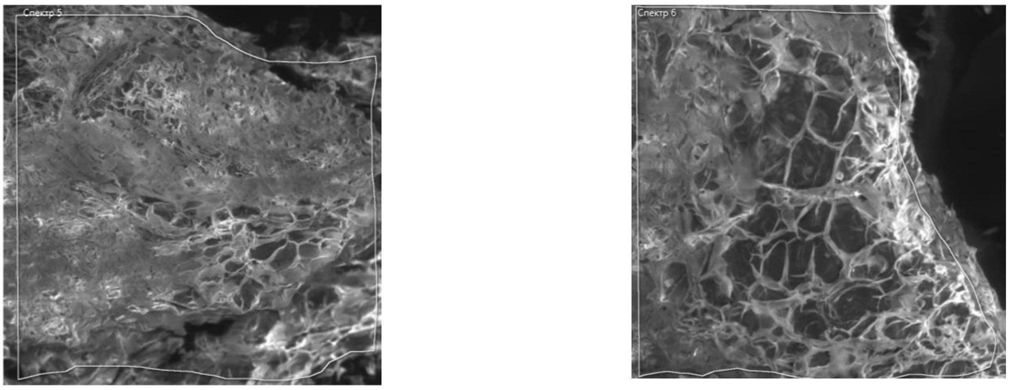
The studied samples were prepared from ripe root vegetables of the following varieties: *Daucus* Shantane, *Beta vulgaris* Bordo 237, *Pastináca sátiva* Bilyi Leleka, *Apium graveolens* Maxim. All vegetables were grown in an open ground at university research plots and harvested at the end of September in 2020. For the study, root vegetables were thoroughly washed by warm water, cleaned of dirt and small roots by a wooden knife and rinsed by clean running water. Residual moisture was absorbed with a towel and then vegetables were peeled. After that vegetables and their peels were cut into slices of 30-50 mm long and 2 mm thick. Particles of peels and main parts of vegetables, without additional chopping, were placed on the lattice of the laboratory infrared dryer and were being dried at a temperature of 45–50°C during 3 hours to achieve mass share of moisture 8–10%. Inside of the dryer, lattices for the material to be dried are located in pairs, one over another, and the panels with heating elements are located above the lattices. Dryer power is 1.8 kW. Dried particles were milled with laboratory disk mill LZM-1 (shaft rotation speed 1047 rad/s) to a size providing full passage of the material through a braided brass sieve №015 (0.15 mm).

Analysis of mass content of micro- elements in the studied samples was performed with the help of detector SEM and EDS based on microscope SEO-SEM Inspect S50-B: AZtecOne microscope with dispersion spectrometer with detector X-MaxN20. The samples to be investigated were pressed into tablets with diameter of 2 mm with polished outer surface. To prevent accumulation of surface charge in electron-probe experiment, samples of dielectric were silvered with a layer of 30-50 nm. Microstructure investigation of powders were performed on a scanning electron microscope REMMA-102 (JSC "SELMI", Sumy). For conducting investigation, a suspension was prepared from the powders. To do this, the powders were being reduced in distilled water at the temperature of 30°C during 20 minutes. The powder suspension was applied to the surface of silicon monocrystal KEF (111) and dried in vacuum until complete evaporation of the solvent. Scanning of sample surfaces was performed using an electron beam with a diameter up to 5 nm with energy of electrons 20 kilowatt. Image multiplicity was 80–800 times, the resolution – 5 nm. Images were obtained in elastically reflected electrons in COMPO mode.

Results of the research and their discussion

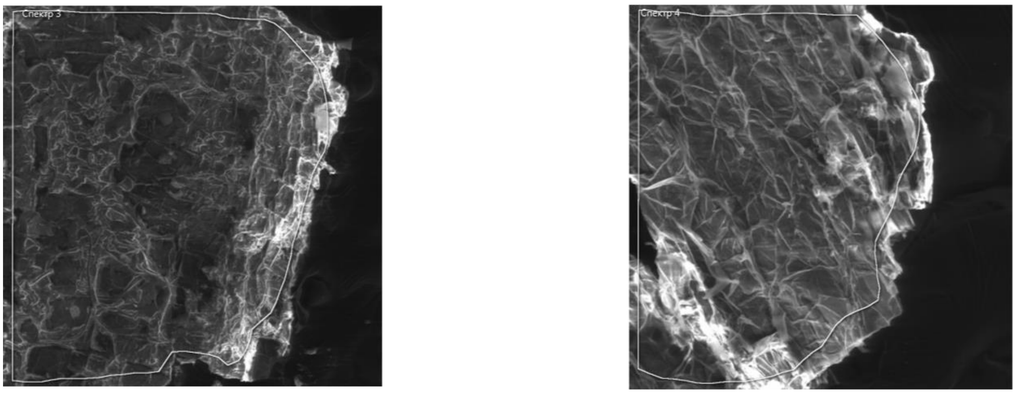
Microstructure analysis (Fig. 1-4) showed availability of dietary fiber which is characterized by high hydrophilicity and ability for swelling and structuring. This microstructure indicates possibility of using powders as stabilizers.

The figures show that all samples consist of polydisperse systems which have different shapes and sizes of crystal particles. Each particle is presented in a form of cells made of mechanical and conductive tubular tissue. Thanks to the sieve-like tubes formed by conductive tissue, liquids can pass freely through them and be kept inside of cells. Conductive tissue of beet powders (Fig. 1) and celery root powders (Fig. 2) is partially destroyed during drying.



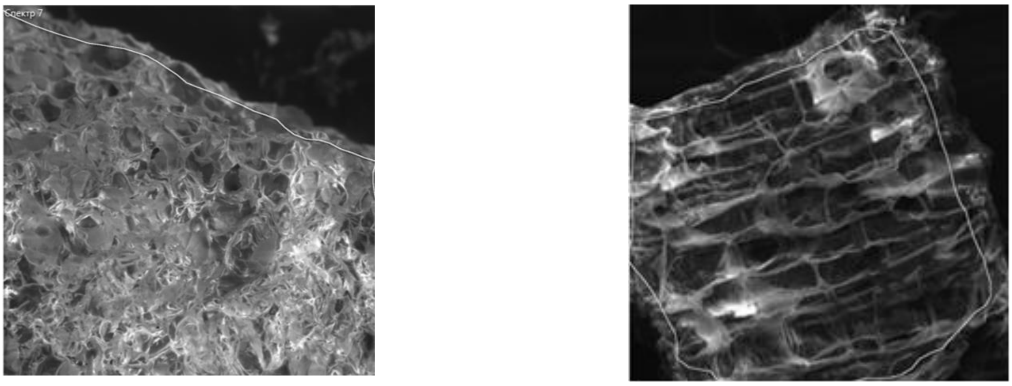
a) b)

Fig. 1. Microstructure of *Beta vulgaris* powder: a – edible root, b – peels (magnification 250μm)



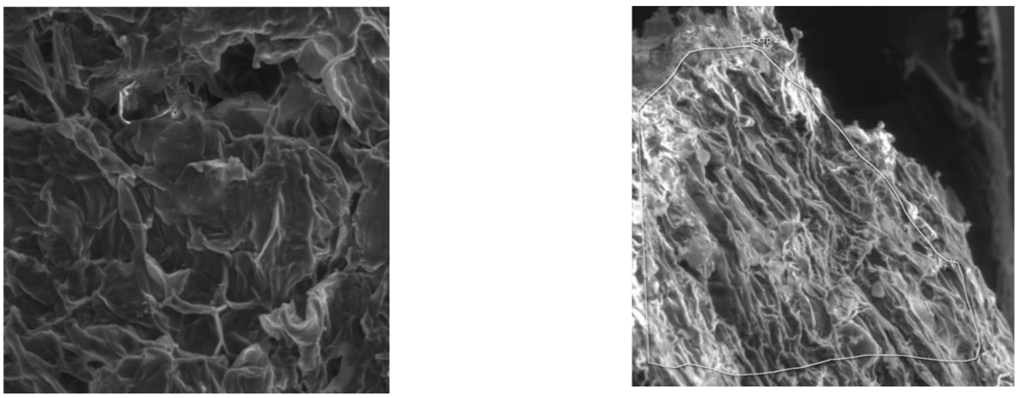
a) b)

Fig. 2. Microstructure of *Daucus* powder: a – edible root, b – peels (magnification: a – 500 μm, b – 250μm)



a) b)

Fig. 3. Microstructure of *Apium graveolens* powder: a – edible root, b – peels (magnification: a – 250 μm, b – 100μm)



a) b)

Fig. 4. Microstructure of *Pastináca sátiva* powder: a – edible root, b – peels (magnification: a – 100 μm, b – 250μm)

This is probably connected with the fact that during heat treatment occurs partial denaturation of tissues. Therefore, we have chosen a drying mode in which this process is not so intense (t = 45–50°C, duration 3 hours).It should be noted that structure of powders made from peels is more distinct and practically does not change under temperature influence, as they mainly consist of conductive tissue. This gives grounds to suggest that they have higher moisture-binding ability. Tubular system formed by conductive tissue creates contact surface of powder-like and liquid phases. The larger area of phase contact, the more intensive liquid penetration into the particles. Figures 1-4 show that the largest contact area is observed in powders made from *Pastináca sátiva* peels. Similar results were obtained by other researchers [43,44].

High content of dietary fiber was observed in all samples. Thermal treatment during drying did not lead to reduction of their content. Similar results are observed during cooking of root vegetables [45].

Porosity of obtained powders (size of free space between powder particles) is slightly different. Emptiness in powders occupies from 50 to 80% of the volume. The greatest porosity is observed in the powder from *Pastináca sátiva* peel, *Pastináca sátiva* edible root and *Apium graveolens* edible root. The smallest one is in *Daucus* edible root powder. The lower density and the greater porosity, the higher level of powder compression. This should be taken into account when implementing technological regime during introduction of powders into recipes of products. As for grain shape in the studied powders, isometric grains are traced in edible roots, and non-isometric (fibrous and lamellar) grains are traced in the peels. Non-isometricity of grains affects their location in the space and leads to anisotropy of the powders. Thus, it can be concluded that vegetable powders have good hydrophilic properties and can be used as structure stabilizers, emulsifiers, moisture retainers and thickeners in the production of different food.

Vegetables contain minerals, mainly K, Ca, Mg, P, Fe. They also contain traces of oligo-elements (S, N), which are absorbed from the soil along with water. Minerals play an important role in water, mineral, protein, fat and carbohydrate metabolism. The results of analysis of the mass ratio of minerals in powders from root vegetables and their peels showed that most of the studied samples of vegetable powders contain potassium (from 6.95 to 31.38%), chlorine (from 0.56 to 6.97%), calcium (from 0 to 6.97%) and nitrogen (from 0 to 4.81%). Silicon was found only in *Apium graveolens* peel in amount of 1.57%.

Comparative analysis of macro- and microelement content in powders made from root vegetables and their peels is presented in Figures 5-8. The content of elements is presented in expressions on dry matter.

Figure 5 shows that *Beta vulgaris* powders do not contain calcium and silicon, but they contain potassium (13.92% in edible root and 16.02% in peel). Potassium regulates water absorbing capacity of cells. However, according to the study of raw *Beta vulgaris* [46], it contains 2% of calcium. According to research of Pakistani scientists [47], the highest amount of potassium was also found in *Beta vulgaris* peel powders. In addition, 39 mg of calcium was found in 100 g of *Beta vulgaris* peel powders. The same researchers showed that *Beta vulgaris* peels contain a significant amount of phosphorus (250 mg/100 g). In our samples, amount of phosphorus was insignificant, only 1.1%. We also did not detect manganese and zinc, in contrast to the results presented in the study [47]. Similar studies were conducted by Nigerian scientists [48]. As well as in our samples, no calcium and zinc were found in *Beta vulgaris* peels. They contained mostly iron (26.46 mg/100 g), potassium (13.82 mg/100 g) and phosphorus (11.57 mg/100 g).

According to our data, Beta vulgaris peel powders contain the highest amount of natrium (4.57%) by 1.27% more than in edible root, chlorine (3.61%) by 2.75% more than in edible root and sulfur (0.61%) by 0.16% more than in edible root. *Beta vulgaris* powders are rich in iron (2.16% in main part and 1.08% in peel), which positively influence blood circulation in the body.

Daucus powders contain K, Ca, Fe, P, Mg, Na, Cl and S. Unlike other vegetable powders, they contain the largest amount of potassium (Fig. 6). Similar results were obtained by other researchers in the analysis of raw *Daucus* [46, 49]. It should be noted that *Daucus* peel contains more potassium (31.38%) than edible root (27.1%), which is 24.43% more than the peel of *Apium graveolens*, 15.36% more than *Beta vulgaris* peel and 21.66% more than *Pastináca sátiva*. The content of phosphorus (4.27%), iron (1.8%) and sulfur (0.59%) in *Daucus* peel is also higher than in edible root. According to the study [47], the highest amount of potassium (1123 mg/100 g) and phosphorus (232 mg/100 g) were also found in *Daucus* peels. A fairly high content of magnesium in *Daucus* peels (167 mg/100 g) was noted, in contrast to our (only 0.32%) powders made from *Daucus* peels. It should be noted that no Cl was found in the peels of vegetables studied by Pakistani scientists. And its content was quite high in our samples: 6.32% in *Beta vulgaris* and 3.61% in *Daucus* peels. This is probably connected with the use of chlorine-containing fertilizers in the growing of root crops (NH_4Cl, $CaCl_2$ and KCl).

Powders from *Apium graveolens* peels contain the highest amount of iron (5.49%), compared to other vegetable powders. In addition, *Apium graveolens* peel contains more magnesium (0.77% against 0.5% in edible root), chlorine (1.12% against. 0.56% in edible root). Magnesium is a structural component of the molecule and a non-protein chemical compound of many ferments; it significantly affects functioning of cellular chromosomes. Calcium (2.86%), natrium (0.74%) and silicon (1.57%) were found only in *Apium graveolens* peel and were not part of the powder from edible part of the vegetable.

Pastináca sátiva peel is inferior to edible root by macro- and microelements (Fig. 8).

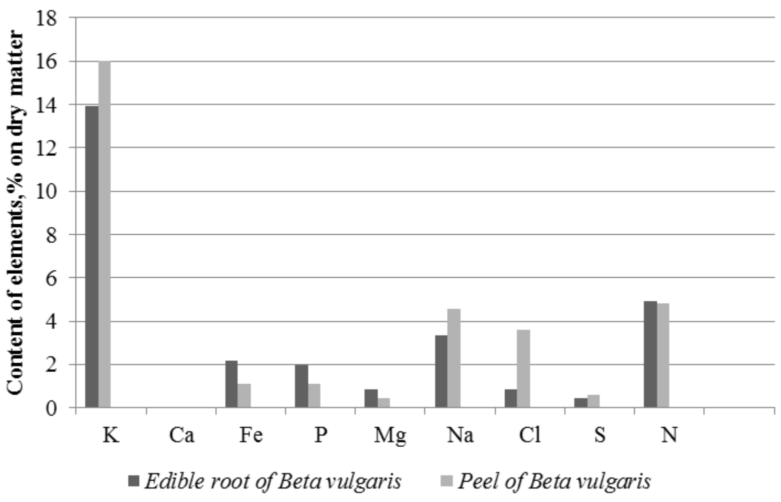


Fig. 5. Content of macro- and microelements in *Beta vulgaris* powders

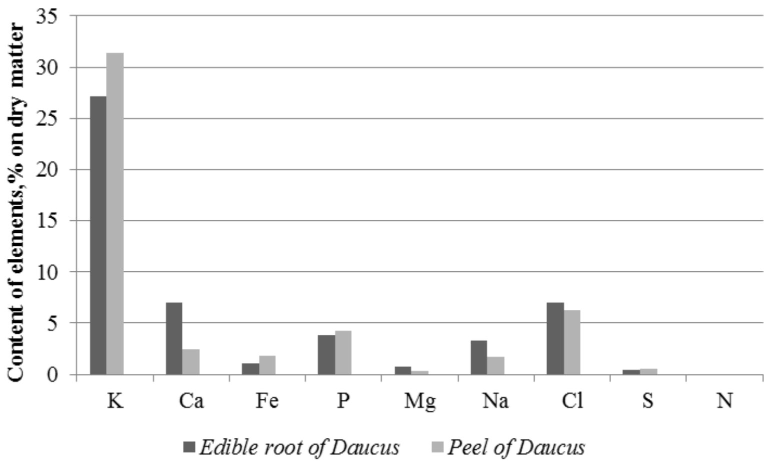


Fig. 6. Content of macro- and microelements in *Daucus* powders

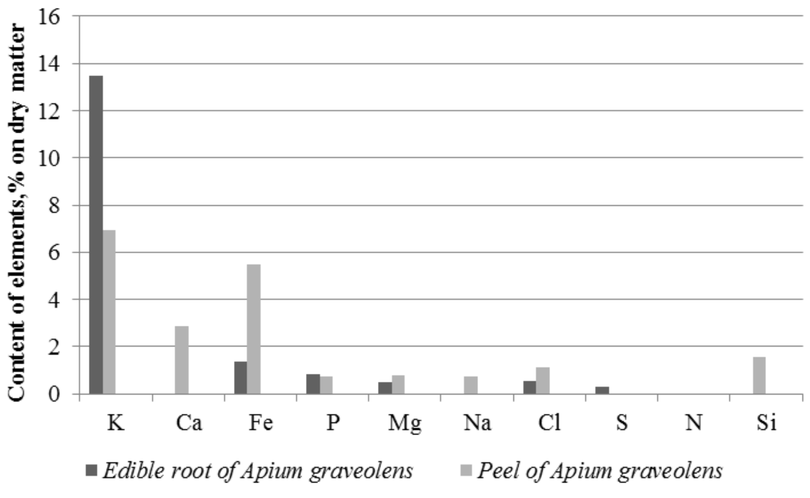


Fig. 7. Content of macro- and microelements in *Apium graveolens* powders

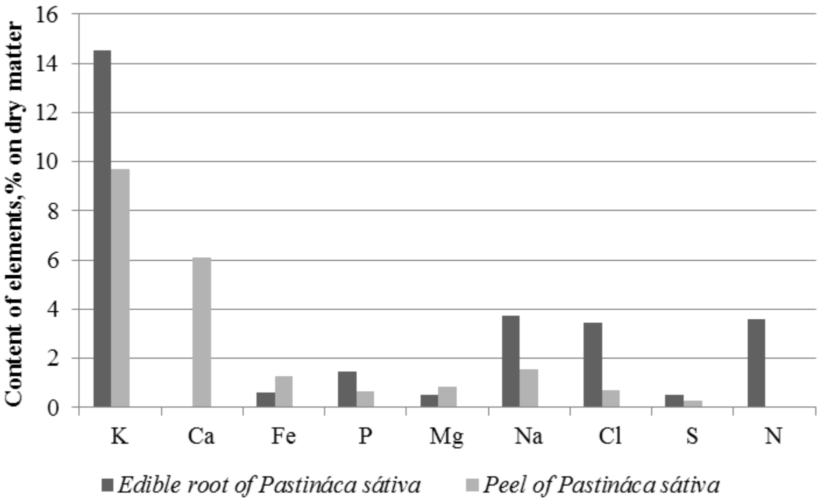


Fig. 8. Content of macro- and microelements in *Pastináca sátiva* powders

The only exceptions are calcium, which is found only in peels (6.12%) and iron (1.27% against 0.6% in edible root). *Pastináca sátiva* peel contains the highest amount of magnesium (0.87%) compared to other root vegetables.

Analysis showed that peels of root vegetables are not inferior in chemical composition and biological value to main (edible) part of the roots. Therefore, it is expedient to process them into powders and use as food additives for functional purposes, rich in macro- and microelements.

Approbation of research results. Technology of complex processing of vegetables into candied fruits and peels into powders with functional effect has been developed [50].

Conclusion

1.Microstructure analysis of vegetable powders made from main (edible) part of root vegetables and their peels showed that all powders are polydisperse, crystalline, porous structures. This structure and shape give them hydrophilic properties. This makes it possible to use them as functional food additives for improvement of structure and moisture retention ability of products, as well as increase of dietary fiber content in them.

2. It has been found that powders from root vegetables (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) and their peels contain irreplaceable macro- and microelements. *Beta vulgaris* powders contain iron (2.16% in edible root and 1.08% in peels). *Daucus* peel contains more potassium (31.38%) than edible part of the root (27.1%). *Apium graveolens* peel powders contain the highest amount of iron (5.49%) compared to other vegetable powders. *Pastináca sátiva* peel is inferior to edible part of the root by mass ratio of macro- and micronutrients. The exceptions are calcium, which is found only in the peel (6.12%) and iron (1.27% against 0.6% in edible root). *Pastináca sátiva* peels contain the highest amount of magnesium (0.87%) compared to other root vegetables.

3. These results indicate the expediency of processing root vegetable waste (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) into functional food additives.

References

1. Ke Qi Lau, Mohd Redzwan Sabran, Siti Raihanah Shafie. Utilization of Vegetable and Fruit By-products as Functional Ingredient and Food. Front Nutr. 2021;8:661693. https://doi.org/ 10.3389/fnut.2021.661693.
2. Chervotkina OO, Oleksiienko VO, Fuchadzhy NO. Ratsionalne vykorystannia vidkhodiv vyrobnytstva morkvianoho soku. Pratsi Tavriiskoho derzhavnoho ahrotekhnolohichnoho universytetu. 2012;4(12):216-221.
3. Raak N, Symmank C, Zahn S, Aschemann-Witzel J, Rohm H. Processing- and product-related causes for food waste and implications for the food supply chain. Waste Manag. 2017;61:461-472. https://doi.org/ 10.1016/j.wasman.2016.12.027.
4. Jiménez-Moreno N, Esparza I, Bimbela F, Gandía LM, Ancín-Azpilicueta C. Valorization of selected fruit and vegetable wastes as bioactive compounds: Opportunities and challenges. Crit. Rev. Environ. Sci. Technol. 2020;50:2061-2108. https://doi.org/ 10.1080/10643389.2019.1694819.
5. Shafiee-Jood M., Cai X. Reducing Food Loss and Waste to Enhance Food Security and Environmental Sustainability. Environ. Sci. Technol. 2016;50:8432-8443. https://doi.org/ 10.1021/acs.est.6b01993.
6. Joglekar SN, Pathak PD, Mandavgane SA, Kulkarni BD. Process of fruit peel waste biorefinery: a case study of citrus waste biorefinery, its environmental impacts and recommendations. Environ. Sci. Pollut. Res. 2019;26:34713-34722. https://doi.org/ 10.1007/s11356-019-04196-0.
7. Senit JJ, Velasco D, Gomez Manrique A, Sanchez-Barba M, Toledo JM, Santos VE, et al. Orange peel waste upstream integrated processing to terpenes, phenolics, pectin and monosaccharides: Optimization approaches. Ind. Crop. Prod. 2019;134:370-381. https://doi.org/ 10.1016/j.indcrop.2019.03.060.

8. Kaisangsri N, Kowalski RJ, Wijesekara I, Kerdchoechuen O, Laohakunjit N, Ganjyal GM. Carrot pomace enhances the expansion and nutritional quality of corn starch extrudates. LWT - Food Science and Technology. 2016;68:391-399. https://doi.org/ 10.1016/j.lwt.2015.12.016.
9. Bergesen HO, Parmann G, Thommessen OB. Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention). Yearb. Int. Coop. Environ. Dev. 2019;1:87-89. https://doi.org/ 10.4324/9781315066547-15.
10. Donner M, Verniquet A, Broeze J, Kayser K, De Vries H. Critical success and risk factors for circular business models valorising agricultural waste and by-products. Resour. Conserv. Recycl. 2021;165:105236. https://doi.org/ 10.1016/j.resconrec.2020.105236.
11. Mohdaly AAA, Sarhan MA, Mahmoud A, Ramadan MF, Smetanska I. Antioxidant efficacy of potato peels and sugar beet pulp extracts in vegetable oils protection. Food Chem. 2010;123(4):1019-1026. https://doi.org/ 10.1016/j.foodchem.2010.05.054.
12. Prashant Sahni. Utilization of fruit and vegetable pomace as functional ingredient in bakery products: A review. Asian Journal of Dairy and Food Research. 2018;37:202-211. https://doi.org/ 10.18805/ajdfr.DR-1369.
13. Curti E, Carini E, Diantom A, Vittadini E. The use of potato fibre to improve bread physico-chemical properties during storage. Food Chem. 2016;195:64-70. https://doi.org/ 10.1016/j.foodchem.2015.03.092.
14. Dhingra D, Michael M, Rajput H. Physico-chemical characteristics of dietary fibre from potato peel and its effect on organoleptic characteristics of biscuits. J Agric Eng. 2012;49(4):25-32.
15. Kumar N, Kumar K. Development of vitamin and dietary fibre enriched carrot pomace and wheat flour based buns. Journal of Pure and Applied Science & Technology 2012;2(1):107-115.
16. Sahni P, Shere DM. Comparative evaluation of physico-chemical and functional properties of apple, carrot and beetroot pomace powders. International Journal of Food and Fermentation Technology. 2017;7(2):317-323. https://doi.org/ 10.5958/2321-5771.2017.00043.6.
17. John J Fitzpatrick, Lilia Ahrné. Food powder handling and processing: Industry problems, knowledge barriers and research opportunities. Chemical Engineering and Processing: Process Intensification. 2005;44(2):209-214. https://doi.org/ 10.1016/j.cep.2004.03.014
18. Bozhko NV, Pasichnyi V, Tischenko V, Svyatnenko R. Effectiveness of natural plant extracts in the technology of combined meatcontaining breads. Ukrainian food journal. 2019;8(3):522-532. https://doi.org/ 10.24263/2304-974X-2019-8-3-9.
19. Schorah CJ. Micronutrients, vitamins and cancer risk. Vit. Horm. 1999;57:1-23. https://doi.org/ 10.1016/s0083-6729(08)60638-x.
20. Stein Z, Susser M, Saenger G, Marolla F. Famine and Human Development: The Dutch Hunger Winter of 1944 – 1945. Journal of Biosocial Science. 1976;8(2):176-179. https://doi.org/ 10.1017/S0021932000010622.
21. Hoebregs H. Fructans in foods and food products, ion_eschange chromatographic method: collaborative study. J. Assoc. Analyt. Chem. Int. 1997;80:1029-1037. https://doi.org/ 10.1093/JAOAC/80.5.1029.
22. Sniezhkin YuF, Petrova ZhO. Kharchovi poroshky z roslynnoi syrovyny. Klasyfikatsiia, metody otrymannia, analiz rynku. Biotechnology. 2010;3(5):43-49.
23. Sadowska-Rociek A, Mickowska B, Cieslik E. Assessment of nutrient content in selected dairy products for compliance with the nutrient content claims. Journal of Microbiology, Biotechnology and Food Sciences. 2013;2(1): 1891-1897.
24. Petrova ZhO. Innovatsiini tekhnolohii vyrobnytstva funktsionalnykh roslynnykh poroshkiv. Naukovi pratsi Odeskoi natsionalnoi akademii kharchovykh tekhnolohii. 2014;46(2):64-69.
25. Dzhum TA, Shcherbakova EV, Khristyuk AV. Perspektivy ispolzovaniya poroshkov fruktov i ovoshchey v obshchestvennom pitanii. Nauchnyy zhurnal KubGAU. 2017;128(04). https://doi.org/ 10.21515/1990-4665-128-089.
26. Samilyk MM, Gelih AO, Kalinkevich OV, Bolgova NV, Shelest IV, Trofimenko YV. et al. Radiomodifying Effect of X-Ray Radiation on Microflora of Yogurts with Ultradisperse Powders of Beta vulgaris. IEEE International Conference on "Nanomaterials: Applications & Properties"; NAP-2020; Sumy, Ukraine; 2020. p. 02IT05-1-02IT05- 5. https://doi.org/ 10.1109 / NAP51477.2020.9309550.
27. Sniezhkin YuF, Petrova ZhO, Paziuk VM. Hidrotermichna obrobka funktsionalnoi syrovyny. Naukovi pratsi Odeskoi natsionalnoi akademii kharchovykh tekhnolohii. 2012;41(1):13-17.
28. Turchyn IM, Voichyshyn AV, Hamkalo KhV. Vykorystannia korenia selery u vyrobnytstvi syrkovykh mas. Vcheni zapysky TNU imeni V.I. Vernadskoho. Seriia: tekhnichni nauky. 2018;29(68):79-84.
29. Golubkina NA, Fedorova MI, Stepanov AN, Nadezhkin SM. Elementnyy sostav pasternaka (pastinaka sativa L.). Ovoshchi Rossii. 2014;3:18-21. https://doi.org/ 10.18619/2072-9146-2014-3-18-21.
30. Martins N, Roriz CL, Morales P, Barros L, Ferreira ICFR. Food colorants: Challenges, opportunities and current desires of agro-industries to ensure consumer expectations and regulatory practices. Trends Food Sci. Technol. 2016;52:1-15. https://doi.org/ 10.1016/J.TIFS.2016.03.009.
31. Tang Y, Cai W, Xu B. Profiles of phenolics, carotenoids and antioxidative capacities of thermal processed white, yellow, orange and purple sweet potatoes grown in Guilin, China. Food Sci. Hum. Wellness. 2015;4(3):123-132. https://doi.org/ 10.1016/j.fshw.2015.07.003.
32. Khan MI, Giridhar P. Plant betalains: Chemistry and biochemistry. Phytochemistry. 2015;117:267-295. https://doi.org/ 10.1016/j.phytochem.2015.06.008.
33. Gérard V, Ay E, Morlet-Savary F, Graff B, Galopin C, Ogren T, et al. Thermal and photochemical stability of anthocyanins from black carrot, grape juice, and purple sweet potato in model beverages in the presence of ascorbic acid. J. Agric. Food Chem. 2019;67(19):5647-5660. https://doi.org/ 10.1021/acs.jafc.9b01672.
34. Downham A, Collins P. Colouring our foods in the last and next millennium. Int. J. Food Sci. Technol. 2000;35:5-22. https://doi.org/ 10.1046/j.1365-2621.2000.00373.x.
35. Hamouz K, Lachman J, Pazderů K, Tomášek J, Hejtmánková K, Pivec V. Differences in anthocyanin content and antioxidant activity of potato tubers with different flesh colour. Plant Soil Environ. 2011;57:478-485. https://doi.org/ 10.17221/265/2011-PSE.
36. Samilyk M, Helikh A, Ryzhkova T, Bolgova N, Nazarenko Y. Influence of the structure of some types of fillers introduced to the yogurt recipe on changes in its rheological indicators. Eastern-European Journal of Enterprise Technologies. 2020;2(11):46-51. https://doi.org/ 10.15587/1729-4061.2020.199527.
37. Raikos V, Neacsu M, Morrice P, Duthie G. Physicochemical stability of egg protein-stabilised oil-in-water emulsions supplemented with vegetable powders. International Journal of Food Science and Technology. 2014;49(11):2433-2440. https://doi.org/ 10.1111/ijfs.12565.
38. Chanika Chimkerd, Thunnalin Winuprasith. Functional properties of vegetable powder and the application in pudding for elderly. Journal of Food Science and Agricultural Technology (JFAT). 2018;4:67-72. https://doi.org/ 104453563.
39. Queiroz VA, da Silva Aguiar A, de Menezes CB, de Carvalho CW, Paiva CL, Fonseca PC, et al. A low calorie and nutritive sorghum powdered drink mix: Influence of tannin on the sensorial and functional properties. J. Cereal Sci. 2018;79:43-49. https://doi.org/ 10.1016/j.jcs.2017.10.001.
40. Sun-Waterhouse D. The development of fruit-based functional foods targeting the health and wellness market: A review. Int. J. Food Sci. Technol. 2011;46:899-920. https://doi.org/ 10.1111/j.1365-2621.2010.02499.x.
41. Hasan MU, Ullah A, Sajid M, Imtiaz A. Modern drying techniques in fruits and vegetables to overcome postharvest losses: A review. J. Food Process. Preserv. 2019;43:1-15. https://doi.org/ 10.1111/jfpp.14280.

42. Karam MC, Petit J, Zimmer D, Baudelaire E, Marie C. Effects of drying and grinding in production of fruit and vegetable powders: A review. J. Food Eng. 2016;188:32-49. https://doi.org/ 10.1016/j.jfoodeng.2016.05.001.
43. Podkovko OA, Rashevs'ka TO. Sostavleniye tekhnologicheskikh-funktsional'nykh kharakteristik poroshkov iz chernogo stolovogo buryaka dlya zastyvaniya v skladskikh pomeshcheniyakh maslyanoy pasti. Tekhníka, energetika, transport APK. 2015;2(90):62-66.
44. Vasheka OM, Rashevs'ka TO. Mikrostruktura vodnykh rozchinovykh poroshkov morkvi, otrimanikh za ríznimi tekhnologíyami sushínnya. Molochna promislovíst'. 2007;2(37):45-50.
45. Johanna Andersson, Gonzalo Garrido-Banuelos, Marion Bergdoll, Francisco Vilaplana, Carolin Menzel, Mihaela Mihnea, Patricia Lopez-Sanchez. Comparison of steaming and boiling of root vegetables for enhancing carbohydrate content and sensory profile. Journal of Food Engineering. 2021;312:110754. https://doi.org/ 10.1016/j.jfoodeng.2021.110754.
46. Monica Butnariu, Alina Butu. Chemical Composition of Vegetables and their Products. Handbook of Food Chemistry. 2014;1-49. https://doi.org/ 10.1007/978-3-642-41609-5_17-1.
47. Khattak KF, Rahman TU. Analysis of vegetable's peels as a natural source of vitamins and minerals. International Food Research Journal. 2017;24(1):292-297.
48. Shuaibu BS, Aremu MO, Kalifa UJ. Chemical Composition and Antioxidant Activities of Beetroot Peel. African Journal of Engineering and Environment Research. 2021;2(1):62-73.
49. Kamlesh Prasad, Raeesul Haq, Vasudha Bansal, Mohammed Wasim Siddiqui, Riadh Ilahy. Carrot: Secondary Metabolites and Their Prospective Health Benefits. Plant Secondary Metabolites: 2016;2:108-194. https://doi.org/ 10.1201/9781315366319-5.
50. Samilyk M, Lukash S, Bolgova N, Helikh A, Maslak N, Maslak O. Advances in Food Processing based on Sustainable Bioeconomy. Journal of Environmental Management and Tourism. 2020;11(5):1105-1113. https://doi.org/ https://doi.org/10.14505//jemt.v11.5(45).08.

ПЕРСПЕКТИВА ПЕРЕРОБКИ І ВИКОРИСТАННЯ ОВОЧЕВИХ ВІДХОДІВ У ВИРОБНИЦТВІ ХАРЧОВИХ ПРОДУКТІВ

М. М. Самілик, кандидат технічних наук, доцент, *E-mail*: maryna.samilyk@snau.edu.ua
Н. В. Болгова, кандидат сільськогосподарських наук, доцент, *E-mail*: natalia.bolhova@snau.edu.ua
Р.В. Цирулик, аспірант, *E-mail:* tigerneon33@gmail.com
Кафедра технологій та безпечності харчових продуктів
Сумський національний аграрний університет, вул. Герасима Кондратьєва, 160, м. Сума, Україна, 40021
Т.М. Рижкова, доктор сільсько-господарських наук, професор, *E-mail:* rujkova.ua@gmail.com
Кафедра технології переробки і стандартизації продуктів тваринництва
Харківська державна зооветеринарна академія
вул. Академічна, 1, смт. Мала Данилівка, Дергачівский р-н, Харківська обл., Україна, 62341

Анотація. Метою даного дослідження є обґрунтування доцільності переробки відходів коренеплідних овочів (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) у харчові добавки функціонального призначення. У статті проаналізовано структуру овочевих порошків та вміст елементів у них (у % на суху речовину). Дослідні зразки було виготовлено із основної частини коренеплодів та їх шкірок. Для виготовлення порошків подрібнені овочі та їх шкірки спочатку висушували у інфрачервоних сушарках протягом 3 годин за температури 45-50°С до масової частки вологи 8–10%. Висушені частинки подрібнювали на лабораторному млині ЛЗМ-1 (швидкість обертання валу 1047 рад/с) до крупності, яка забезпечує повний прохід матеріалу через сито №015 (δ>100). Методом електронної мікроскопії досліджено структуру овочевих порошків. Встановлено, що всі овочеві порошки мають кристалічну пористу структуру, а відповідно - гідрофільні властивості. Це дає можливість їх використання при виробництві харчових продуктів в якості стабілізаторів структури, емульгаторів та вологоутримувачів. Дослідження вмісту деяких мінеральних речовин в зразках проводили за допомогою детектора SEM та EDS на основі мікроскопа. Встановлено, що овочеві порошки містять ессенціальні макроелементи (K, Na, Ca, P, Cl, S, N), незамінні мікроелементи (Fe, Mg) та умовно життєво необхідний мікроелемент Si, який виявлено лише в порошку, виготовленому із шкірок селери. Дослідження показало, що бурякові порошки багаті на залізо (2,16% міститься в коренеплоді та 1,08% у шкірці). У порошку із шкірки моркви міститься більше калію (31,38%), ніж у порошку, виготовленому із основної частини коренеплоду (27,1%). Порошки із шкірки селери містять найбільшу кількість заліза (5,49%), в порівнянні з іншими овочевими порошками. Порошок зі шкіри пастернака за масовим співвідношенням макро- та мікроелементів поступається основній частині коренеплоду. Винятком є лише кальцій, який міститься тільки в шкірці (6,12%) та залізо (1,27% проти 0,6% у коренеплоді). Шкірка пастернака містить найбільшу кількість магнію (0,87%) порівняно з іншими коренеплодами. Такі результати свідчать про доцільність переробки відходів коренеплідних овочів (*Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*) у харчові добавки функціонального призначення.

Ключові слова: *Beta vulgaris, Daucus, Apium graveolens, Pastináca sátiva*, овочеві шкірки, харчові добавки функціонального призначення, сушіння.