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THE USE OF VEGETABLE POMACE IN THE PRODUCTION OF FUNCTIONAL FOOD AND FEED PRODUCTS

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B. Iegorov[1], Doctor of Technical Sciences, Professor, Academician of the National Academy of Agrarian Sciences
A. Iegorova[2], Candidate of Technical Sciences, Associate Professor
A. Makarynska[1], Doctor of Technical Sciences, Professor
M. Kashkano[3], Candidate of Technical Sciences, Associate Professor
F.Marchenkov[4], Research and Development Director
[1] Department of Grain and Feed Technology
[2] Department of Food Chemistry, Expertise, and Biotechnologies
[3] Department of Restaurant and Wellness Food Technology
Odesa National University of Technology,
112 Kanatna Street, Odesa, Ukraine 65039
[4] Biocontact Ltd, 39 Kostyuka Street, Kyiv, Ukraine 03170

Correspondence:
B. Iegorov
E-mail: bogdanegoroff58@gmail.com

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Abstract. This research addresses the pressing issue of utilizing by-products from vegetable processing to develop functional food products and animal feed. In the context of increasing physiological stress and environmental degradation, the advancement of nutritional trends and the consumption of vegetable juices have become critical factors in maintaining public health. The production of carrot, pumpkin, and beetroot juices results in the accumulation of significant amounts of pomace (30–50%). Due to high moisture content, these by-products are highly perishable; however, they retain between 50% and 90% of the antioxidants and bioactive compounds found in the raw materials. This study provides a comparative analysis of the physicochemical properties of pomace obtained through screw-press and centrifugal extraction methods. It was established that the screw-press method results in a lower pomace yield (25.5–28.7%) and a reduction in moisture content by 6.5–9.17% compared to centrifugation. These findings suggest that screw-press extraction produces raw material that is potentially more viable and cost-effective for subsequent processing.The scientific novelty of this study lies in the substantiation of the prebiotic potential of vegetable pomace through the investigation of its impact on the growth of *Lactobacillus plantarum* and *Bifidobacterium adolescentis* cultures. It has been experimentally proven that the use of screw-pressed carrot pomace stimulates the growth of lactobacilli twice as effectively as the control, while screw-pressed beetroot pomace increases growth by 1.3 times. Simultaneously, for bifidobacteria, the most significant stimulating effect (21.7% higher than the control) was recorded with the addition of screw-pressed beetroot pomace, whereas centrifugally extracted pumpkin pomace improved growth by 17%. These results confirm a consistent correlation between the juice extraction method and the quality and functional properties of the resulting secondary raw materials. The practical significance of the research consists in the application of these established patterns to design the composition of health-promoting (functional) food products. This approach not only enhances their biological value but also contributes to the sustainable management and rational utilization of waste in the vegetable processing industry.

Keywords: functional food and feed products, vegetable juices, centrifugal and screw extraction methods, carrot, pumpkin and beetroot pomace, prebiotic effect.

Introduction. Formulation of the problem

The increasing stress levels on the population, deteriorating environmental conditions, and a growing focus on the trend of longevity and healthy living are accelerating the development of health-promoting nutrition trends [1]. Among various factors and recommendations, these trends emphasize the consumption of vegetable juices [2, 3].

Today, driven by healthy eating trends, vegetable juices made from pumpkin, carrot, and beetroot are the most popular [4, 5, 6]. However, their production generates a significant amount of by-products (ranging from 30% to 50%) in the form of vegetable pomace, which serves as a valuable raw material for manufacturing functional food and feed products. Due to their high moisture content and nutrient density, which promote microbial growth, such pomace residues are not suitable for long-term storage. Specifically, the moisture content in vegetable pomace after juice extraction typically ranges from 60% to over 85%, depending on the extraction method and pressing efficiency [7].

The challenges of further processing vegetable pomace have been addressed in research laboratories at numerous universities worldwide. Typically, such pomace is dried to a moisture content of no more than 13–14%. However, high energy costs increase the price of the final products, rendering them economically inefficient or entirely non-viable [8]. Jordan Richards et al. investigated the impact of physical pretreatment – hydraulic pressing combined with two drying methods (freeze-drying and dehydration) – on the functional, chemical, and physical properties of carrot pomace. They established a significant improvement in water-holding capacity, oil-binding capacity, and swelling capacity, particularly when freeze-drying was employed [9]. Freeze-dried pomace retained up to 33% more carotenoids and exhibited a 22% increase in water-holding capacity compared to dehydrated samples, thereby enhancing the economic feasibility of using such a product as a technological fortifying additive in functional food production [9]. Evelina Höglund et al. investigated the efficiency of drying berry pomace using hot air and microwaves in combination with the extrusion of whole-grain rye flour supplemented with 25% blueberry powder. This approach enabled the production of value-added extruded food products [10]. While this method allows for the incorporation of up to 25% fruit and vegetable pomace powders into the extrudate, the use of predrying – even under mild conditions – and extrusion at temperatures ranging from 128°C to 135°C leads to significant losses of bioactive compounds [10].

The extrusion of vegetable and grain mixtures typically reduces the content of bioactive compounds, such as vitamins, phenols, and antioxidants, primarily due to high pressure and temperature. However, this process may simultaneously enhance their bioavailability by disrupting cellular structures [11]. While losses are significantly dependent on extrusion parameters, temperature remains the primary factor. For instance, research by Silvia Mironeasa et al. established that the loss of total phenolic content during the extrusion of such mixtures is approximately 15–18% [11].

Vegetable pomace retained after juice extraction possesses high nutritional value. This is particularly significant for the production of functional food and feed products, driving the search for effective technological solutions for their further processing and utilization.

Analysis of recent research and publications

During the processing of vegetables into juice, a significant portion of bioactive compounds – including dietary fibers, polyphenols, carotenoids, and vitamins – remains in the processing by-products rather than in the juices. Research conducted by Filomena Carvalho et al. established that 50% to 90% of antioxidants and other bioactive substances are retained in the pomace during the production of vegetable juices [12].

According to Roxana Nicoleta Gavril et al., the pomace yield in pumpkin juice production ranges from 30% to 50% [13]. Pumpkin pomace is a rich source of dietary fiber, vitamins, minerals, and carbohydrates, characterized by a high content of carotenoids (35–40 mg/100 g dry matter), minerals (calcium: 90 mg/100 g; phosphorus: 14 mg/100 g), cellulose (19.6%), hemicellulose (3.5%), and pectin (5.4%) [14]. Due to their low energy value, dietary fibers derived from pumpkin pulp are highly beneficial for lowering blood glucose levels [15]. Traditionally, pumpkin has been consumed by humans to treat diabetes [16]. Research by Zunaira Arshad et al. demonstrated the antimicrobial and antioxidant potential of pumpkin pulp [17]. Furthermore, study by Xin-En Huang et al. proved the anticarcinogenic properties of pumpkin, showing that its consumption significantly helps prevent gastric, breast, lung, and colorectal cancers [18]. Mukesh Yadav et al. state that incorporating pumpkin into the daily diet can provide various health benefits and improve overall wellness due to its antidiabetic, anticarcinogenic, antioxidant, and antimicrobial potentials, as well as its ability to inhibit kidney stone formation and its hypotensive, anti-inflammatory, and hematopoietic effects [19].

The yield of carrot pomace ranges from 30% to 50% when using traditional juice production methods, and can be reduced to between 10% and 20% with the application of modern technologies [20, 21].

On a dry matter basis, carrot pomace contains 4%–5% protein, 8%–9% reducing sugars, 5%–6% minerals, 28% cellulose, 2.1% pectin, 6.7% hemicellulose, and 17.5% lignin. It also serves as a significant source of bioactive compounds such as phenolic compounds and polyacetylenes [22, 23]. Carrot pomace is rich in microelements, including sodium (3.2 mg/g), potassium (18.6 mg/g), phosphorus (1.8 mg/g), calcium (3.0 mg/g), magnesium (1.1 mg/g), copper (4.0 mg/g), manganese (10.8 mg/g), iron (30.5 mg/g), and zinc (29.4 mg/g). Furthermore, it contains vitamins such as thiamine, riboflavin, and other B-group vitamins, vitamin A, tocopherols, and ascorbic acid, with β-carotene content ranging from 1.8 to 6.3 g/kg [23]. Carotenoids contribute to strengthening the immune system and reducing the risk of diseases such as cancer, cardiovascular disorders, age-related macular degeneration, and cataract formation; they have also been identified as potential inhibitors of Alzheimer’s disease [24]. When drying carrot waste using traditional methods, β-carotene losses typically exceed 40 %.

According to Marta Igual et al., the pomace yield from processing beetroot into juice is at least 40% [25]. Beetroot contains various bioactive phytochemicals, such as betalains (e.g., betacyanins and betaxanthins), flavonoids, polyphenols, saponins, and inorganic nitrate

(NO_3). It also includes macroelements such as K, Na, P, Ca, and Mg, as well as microelements such as Cu, Fe, Zn, and Mn [26]. According to a review by Liping Chen et al., due to its high content of bioactive compounds, beetroot possesses antitumor properties, helps lower blood pressure, positively influences microvascular vasodilation, supports glucose homeostasis, exhibits a protective effect against oxidative stress, prevents systemic liver damage, and improves cerebral blood flow parameters [27].

Problem statement. An analysis of vegetable juice production methods indicates varying effects on the composition of nutrients and bioactive compounds in both juices and pomace, depending on the manufacturing process. The expansion of the market for healthy and natural juices has led to the development and implementation of novel technologies using pulsed electric fields, high hydrostatic pressure, ultrasound, and microwaves. These methods have been shown to increase juice yield and the content of flavonoids, phenolic compounds, and antioxidants, though they are often accompanied by increased turbidity [28]. Consequently, screw pressing and centrifugal extraction remain the most widely used methods in industrial vegetable juice production [29]. Cold pressing, the most common process in the commercial production of juices from fresh fruits and vegetables without heat application, differs from centrifugation by providing higher juice yields and superior preservation of bioactive substances and sensory components, positioning these juices in the premium category [30]. Although the use of centrifuges enhances the productivity of the extraction process, it causes significant oxidation of bioactive components due to high-speed mixing, which introduces oxygen and generates heat. This accelerates enzymatic browning by polyphenol oxidase and oxidizes polyphenols (e.g., chlorogenic acid) into reactive quinones, negatively affecting the color and nutritional value of the juices [31]. Simultaneously, both screw and centrifugal production methods yield important by-products – pomace – which possess distinct physical and chemical properties [30, 31], as described in the preceding literature review. However, there is currently a lack of published data justifying the utilization of pomace obtained through different extraction methods for the production of functional food and feed products.

Research materials and methods

The research materials for comparative analysis included data from previous studies by other authors, as well as samples of carrot, pumpkin, and beetroot pomace. These samples were obtained during vegetable juice production using screw and centrifugal extraction methods, specifically utilizing the Vector AH-ZJ1T screw juicer and the Vektor 2000KP centrifugal juicer. The feasibility of using vegetable pomace for the production of functional food and feed products was determined based on the level of their prebiotic effect.

To determine the prebiotic effect, conventional microbiological methods were employed, including the inoculation of cultures from the genus *Bifidobacterium* (species *Bifidobacterium adolescentis*) and the genus *Lactobacillus* (species *Lactobacillus plantarum*) onto nutrient media. The research further involved microscopy, isolation, identification, and enumeration of the microorganisms.

Results of the research and their discussion

During the research, the processing yield and moisture content were determined for the pomace samples of carrot, pumpkin, and table beet. These samples were obtained during vegetable juice production using screw and centrifugal extraction methods (Table 1).

Table 1 – Yield and moisture content of vegetable pomace obtained after juice production

№	Sample	Yield, %,	Moisture content, %
1.	Centrifugal carrot pomace	32,7±0,12	84,5±0,55
2.	Screw carrot pomace	25,5±0,11	77,4±0,47
3.	Centrifugal pumpkin pomace	38,4±0,17	87,7±0,68
4.	Screw pumpkin pomace	28,7±0,16	82,3±0,73
5.	Centrifugal beetroot pomace	39,2±0,14	86,1±0,64
6.	Screw beetroot pomace	26,3±0,15	80,2±0,58

As indicated by the data, the yield of vegetable pomace during juice extraction using the screw method ranged from 25.5% to 28.7%, whereas the centrifugal method resulted in a yield of 32.7–39.2%. The moisture content was 6.5–9.17% higher in the vegetable pomace obtained via the centrifugal method compared to the screw extraction method

Subsequently, sterilized samples of extruded corn flour (control) and experimental samples of sterilized carrot, pumpkin, and table beet pomace (obtained via both screw and centrifugal extraction) were introduced into a sterile nutrient medium. This was followed by the microbiological inoculation of cultures from the genus *Bifidobacterium* (species *Bifidobacterium adolescentis*) and the genus *Lactobacillus* (species *Lactobacillus plantarum*). Extruded corn flour was selected as the control due to its high prebiotic effect and widespread use in the production of functional food and feed products, as established in previous studies [34].The growth results of *Lactobacillus plantarum* are presented in Fig. 1.

As observed, pumpkin pomace obtained by both centrifugal and screw methods exhibited a lower prebiotic effect on *Lactobacillus plantarum* compared to the extruded corn control

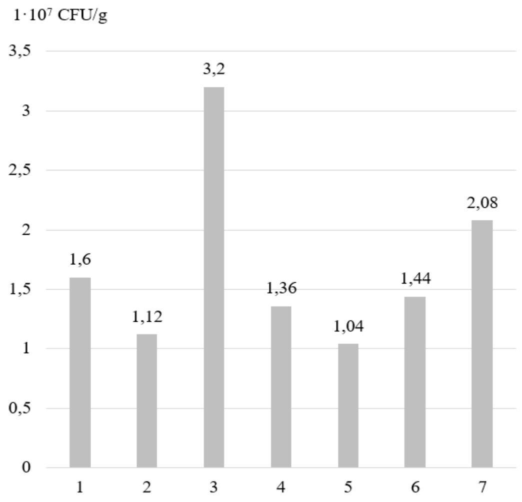

Fig. 1. Growth results of *Lactobacillus plantarum* on nutrient media supplemented with: (1) extruded corn flour; (2) centrifugal and (3) screw carrot pomace; (4) centrifugal and (5) screw pumpkin pomace; (6) centrifugal and (7) screw beetroot pomace

Carrot and beetroot pomaces obtained via the screw method showed higher prebiotic potential than those produced by the centrifugal method. Specifically, the bacterial count of *Lactobacillus plantarum* in the medium supplemented with screw-pressed carrot pomace was 2.0 times higher than in the control (1). Similarly, the concentration of *Lactobacillus plantarum* with screw-pressed beetroot pomace was 1.3 times higher than in the control (1). These results support the findings of Donaldson M. [30] and Gholamreza Khaksar et al. [31] regarding the superior preservation of biologically active substances in vegetable pomace when using screw pressing compared to centrifugal juice production.

The growth results of *Bifidobacterium adolescentis* are presented in Fig. 2. As observed, the bacterial count of *Bifidobacterium adolescentis* in samples containing both screw-pressed and centrifugal carrot pomace was twofold lower than in the sample supplemented with extruded corn flour (control). It was found that centrifugal pumpkin pomace (4) promoted better growth of *Bifidobacterium adolescentis*, showing a 17% increase compared to the control. The best result was observed when the nutrient medium was supplemented with screw-pressed beetroot pomace (7). In this case, the bacterial count of *Bifidobacterium adolescentis* was 21.7% higher than that of the control.

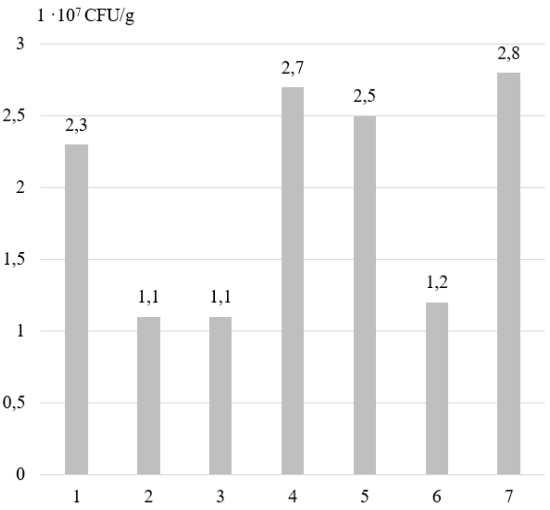

Fig. 2. Growth results of *Bifidobacterium adolescentis* bacteria on nutrient media supplemented with extruded corn grain flour (1), centrifugal (2) and screw-pressed (3) carrot pomace, centrifugal (4) and screw-pressed (5) pumpkin pomace, and centrifugal (6) and screw-pressed (7) beet pomace.

Conclusion

The results of the conducted research established that higher juice yield – and consequently, a lower yield of vegetable pomace – is achieved using the screw pressing method (ranging from 25.5% to 28.7% for pomace). Claims by numerous researchers regarding the negative impact of centrifugal extraction on the quality of both juices and pomace were confirmed by the results of cultivating beneficial bacteria on nutrient media supplemented with vegetable pomace obtained by different methods. Specifically, the count of *Lactobacillus plantarum* in the medium supplemented with screw-pressed carrot pomace was 2.0 times higher than in the control. Similarly, the concentration of *Lactobacillus plantarum* with screw-pressed beetroot pomace exceeded the control by 1.3 times.

At the same time, centrifugal pumpkin pomace enhanced the growth of *Bifidobacterium adolescentis* by 17%, while screw-pressed beetroot pomace resulted in a 21.7% increase compared to the control. Consequently, a clear dependence of the prebiotic effect on the method of vegetable juice extraction and pomace production has been established. This relationship must be taken into account in the manufacturing of functional food and feed products

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ВИКОРИСТАННЯ РОСЛИННИХ ВИЖИМКІВ У ВИРОБНИЦТВІ ФУНКЦІОНАЛЬНИХ ХАРЧОВИХ ТА КОРМОВИХ ПРОДУКТІВ

Б.В. Єгоров[1] доктор технічних наук, професор, академік Національної академії аграрних наук, *E-mail*: bogdanegoroff58@gmail.com
А.В. Єгорова[2]**,** кандидат технічних наук, доцент, *E-mail*: antoninaegorova59@gmail.com
А.В. Макаринська[1], доктор технічних наук, професор, *E-mail*: allavm2015@gmail.com
М.А. Кашкано[3], кандидат технічних наук, доцент, *E-mail*: maryanakashkano@gmail.com
Ф.С. Марченков[4], Заступник директора з наукової роботи, *E-mail*: marchenkov150@gmail.com
[1] кафедра технології зерна і комбікормів
[2]кафедра харчової хімії, експертизи та біотехнологій
[3]кафедра технології ресторанного і оздоровчого харчування
Одеський національний технологічний університет
вул. Канатна, 112, м. Одеса, Україна, 65039
[4]ТОВ «Біоконтакт», вул. Костюка, м. Київ, 39 Україна03170,

Анотація. Це дослідження стосується актуального питання використання побічних продуктів переробки овочів для розробки функціональних харчових продуктів та кормів для тварин. В умовах зростаючого фізіологічного стресу та погіршення стану навколишнього середовища, розвиток харчових тенденцій та споживання овочевих соків стали критичними факторами для підтримки здоров'я населення. Виробництво морквяного, гарбузового та бурякового соків призводить до накопичення значної кількості вичавок (30–50%). Через високий вміст вологи ці побічні продукти є швидкопсувними; однак вони зберігають від 50% до 90% антиоксидантів та біоактивних сполук, що містяться в сировині. Це дослідження пропонує порівняльний аналіз фізико-хімічних властивостей вичавок, отриманих методами шнекового пресування та відцентрової екстракції. Було встановлено, що метод шнекового пресування призводить до нижчого виходу вичавок (25,5–28,7%) та зниження вмісту вологи на 6,5–9,17% порівняно з центрифугуванням. Ці результати свідчать про те, що шнекова екстракція дозволяє отримати сировину, яка є потенційно більш життєздатною та економічно ефективною для подальшої переробки. Наукова новизна цього дослідження полягає в обґрунтуванні пребіотичного потенціалу овочевих вичавок шляхом дослідження їх впливу на ріст культур Lactobacillus plantarum та Bifidobacterium adolescentis. Експериментально доведено, що використання шнеково пресованих морквяних вичавок стимулює ріст лактобактерій вдвічі ефективніше, ніж контроль, тоді як шнеково пресовані бурякові вичавки збільшують ріст у 1,3 раза. Одночасно для біфідобактерій найбільш значний стимулюючий ефект (на 21,7% вище, ніж у контролі) був зафіксований при додаванні шнеково пресованих бурякових вичавок, тоді як центрифужно екстраговані гарбузові вичавки покращили ріст на 17%. Ці результати підтверджують послідовну кореляцію між методом екстракції соку та якістю та функціональними властивостями отриманої вторинної сировини. Практичне значення дослідження полягає у застосуванні цих встановлених закономірностей для розробки складу оздоровчих (функціональних) харчових продуктів. Такий підхід не лише підвищує їхню біологічну цінність, але й сприяє сталому управлінню та раціональному використанню відходів у овочепереробній промисловості.

Ключові слова: функціональні харчові продукти та корми, овочеві соки, методи відцентрової та шнекової екстракції, морквяний, гарбузовий та буряковий вичавки, пребіотичний ефект.

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