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Whole Wheat Bread with Grape Seed Powder

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Among the various by-products of grape processing, Pink Muscat grape seed powder is notable for its rich biochemical composition, which offers distinct advantages when incorporated into food products like bread. The study aims to develop whole wheat bread with grape seed powder. The research was conducted at the Bakery Products Laboratory of the Tver State Agricultural Academy (Tver, Russia). The powder used in the experiments was made from the cake of Pink Muscat grape seeds. The results demonstrated significant improvements in bread quality, with notable enhancements in nutritional content, including increased antioxidant properties, as well as better sensory characteristics such as taste, texture, and aroma. Organoleptic and physicochemical parameters were determined using well-proven and widely known methods and equipment. As part of the research program, the authors developed the formulation of experimental products where whole wheat flour was partially replaced with grape seed powder. The experimental research resulted in the formulation of a promising bakery product that effectively combines the beneficial properties of whole-grain wheat flour and grape seed powder. The most optimal dosage of the phytoadditive was 7.5% of flour weight. Promising directions for further research include the introduction of grape seed powder into the composition of polycomponent mixes for comprehensive enrichment of bakery products, increasing their functional, therapeutic, and preventive characteristics.

Keywords: Powdered product, formulation, quality assessment, food production, food industry.

INTRODUCTION

Grapes, a berry, are one of the most highly consumed fruits across the world with a rich history. In addition to its pharmaceutical benefits, grape seed extracts (GSE) have amassed significant attention in the food industry for their ecological and economic benefits. As a waste from wineries, juice factories, and other industries, discarded grape seeds make up the bulk of agricultural waste. Utilizing grape seed extracts reduces waste, optimizes resources, and aligns with sustainable practices (Maamoun, 2022).

Economically, GSE have a wide range of current and potential applications in the food industry. Grape seed extracts can be applied as food preservatives due to their quality as a natural antioxidant with no side effects. Current research has shown that they showed good effects in extending the shelf life of baked goods, mushrooms, and meat. They also showed effects in oxidation of lipids, pathogen inhibition, and reduction in fruit weight loss. It also offered a cost-effective alternative to synthetic preservatives (Chen *et al.*, 2020). Research has also shown that they can be used as essential additives to food supplements and in the production of edible, non-toxic, biodegradable food coatings (Chen *et al.*, 2020). Furthermore, studies have shown the potential application of grape seed extracts as a substitute for producing nitrite-free food and in the production of grape seed oil.

Complete processing of agricultural raw materials is an essential task of the agro-industrial complex (Koç and Atar Kayabaşi, 2023; Serekpayev *et al.*, 2016; Vasilev *et al.*, 2019). The development of zero-waste technologies requires timely adaptation of the processing industry (Khokonova *et al.*, 2024; Naliukhin *et al.*, 2024). The most acute problem is processing the by-products of plant raw materials represented by a wide range of products: peels, seeds, pits, stems, pericarp, etc. (Miolla *et al.*, 2023). Each product has by-products. Among the wide range of by-product resources, the amount of grape processing by-products is particularly significant (Oganesyants *et al.*, 2019; Siller-Sánchez *et al.*, 2024). The fruits of this plant are widely used to produce wine

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and juice (Mammadova *et al*., 2020; Nowshehri *et al*., 2015). This leaves a significant amount of grape pomace, consisting mainly of the skin and seeds (Lou *et al*., 2021). These materials have exceptional characteristics, containing a significant amount of biologically active substances (macro-, and microelements, phenolic compounds, vitamins, etc.) (Abouelenein *et al*., 2023). According to expert estimates, in the structure of the solid phase of grape pomace, the skin accounts for about 60% and the seeds for about 40%. The greatest difficulties are faced when utilizing the seeds, owing to this material's physical and mechanical characteristics and rich biochemical composition. Most experts agree that grape seeds should be widely used in the food and pharmaceutical industries (Abdel-Khalek and Mattar, 2022; Hegedüs *et al*., 2022; Khan *et al*., 2021). An additional factor amplifying the scientific community's attention to this issue is the need to improve the environmental safety of production, as significant amounts of grape pomace often accumulate near wineries, requiring further utilization (Salem *et al*., 2022).

In practice, the processing of grape seeds into powders, as a rule, uses two-stage technology. At the first stage, pressing is performed to obtain grapeseed oil rich in vitamin E and antioxidants, and the second stage involves grinding the remaining cake. In this process, the key element is the degree of grinding of the raw material, because the seed's outer shell is tough and, if ground insufficiently, can adversely affect the organoleptic quality of the products (Bolenz and Glöde, 2021). The optimal grind is with a particle size not exceeding 30-50 micrometers (Smolianova and Voloshina, 2019). This finely ground material is an excellent ingredient for effective incorporation into food products, especially those consumed daily. Among such products, bakery products consumed by most of the world's population have significant competitive advantages (Miolla *et al*., 2023). Thus, improving the health-saving characteristics of this group of products is an important task for the food industry. Some scientific literature covers individual aspects of applying grape seed powder in bakery products (Elkatry *et al*., 2022; Grinvald *et al*., 2024; Merenkova *et al*., 2021; Oprea *et al*., 2022).

The research hypothesis posed in this study is that using grape processing by-products improves the characteristics of bakery products.

The study aimed to develop whole wheat bread with grape seed powder.

The research objectives were: 1) to develop the formulation of the new product; 2) to produce experimental products and study their quality characteristics.

MATERIALS AND METHODS

***Research design*:** The research was conducted in 2024 at the Bakery Products Laboratory of the Tver State Agricultural Academy (Tver, Russia).

***Materials of the research*:** The powder used in the experiments was made from the cake of Pink Muscat grape seeds (Solnechnaya Dolina JSC, Russia) left over from cold-pressing grapeseed oil. The whole-grain flour for the bread was produced from the food grain of winter wheat of the Mera variety. The wheat of this variety is characterized by excellent baking properties (bread volume yield and flour strength). The biochemical composition of grape seed cake per 100 g of raw material in mg can be seen in Figure 1.

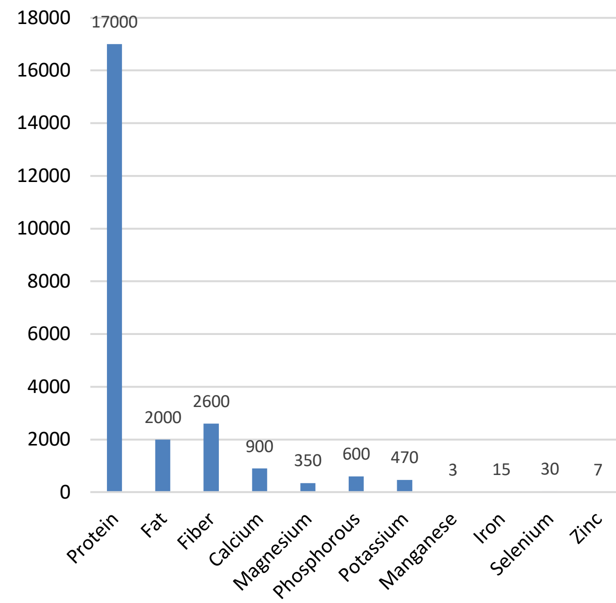

Figure 1. Composition of grape seed cake (mg).

For better grinding, the cake was dried to constant moisture content in a ShS-2/80-SPU drying cabinet (Smolensk SKTB SPU, Russia) at 60-70°C. After drying, the plant material was ground with an LM-202 laboratory mill (Plaun LLC, Russia). The ground product was separated into fractions using a U1-ERL-10-3 laboratory sieve (Zernotekhnika LLC, Russia). A fraction smaller than 50 micrometers was used in subsequent bread-making (Fig. 2).

Figure 2. Grape seed powder.

The test bread dough sample was prepared following the no-starter method, which consisted in putting all ingredients simultaneously into the bowl of a Fimar IM7SNGX405T dough mixer (Fimar S.p.A., Italy). Next, the dough was placed in the mold and proofed in a Smeg LEV31RU proofing cabinet (Smeg S.p.A., Italy) at 35°C for 1 hour. The products were then baked in a Smeg Alfa 41 convection oven (Smeg S.p.A., Italy) at 200°C for 30 minutes.

***Instruments and methods of the research*:** The research process followed commonly employed methodologies. In the comparative analysis aimed at identifying the specific characteristics of the products, the control sample was wheat bread produced according to the National Standard of the Russian Federation GOST 58233-2018 (Rosstandart, 2019).

The experimental work was carried out following the methods prescribed by normative standardization documents: GOST 5667-2022 for collecting samples and determining organoleptic parameters (Rosstandart, 2022a), GOST 21094-2022 for determining moisture content (Rosstandart, 2022b), GOST 5670-96 for determining acidity (State Standard of Russia, 2006b), and GOST 5669-96 for determining porosity (State Standard of Russia, 2006a). The specific volume of bread (V_1) was determined using the formula $V_1=V_2/M$, where V_2 is the volume of bread in the form, and M is the mass of bread before cooling. Weighing in the process of determining parameters was performed using a VST-600/10 electronic scale (Ves-Servis CJSC, Russia).

The porosity of the products was determined using a Zhuravlev PZh-1M device (Scientific Production Association Priborinform LLC, Russia), which cut out cylindrical samples of the crumb, 27 cm^3 each for subsequent weighing. Posorisy was calculated using the formula $P= [(V-m/p)/V]\cdot 100$, where V is the total volume of the samples, cm^3; m – the total mass of the samples, g; p – the density of the crumb without pores (for whole wheat flour products 1.21).

***Research stages*:** A commission of 10 experts conducted the organoleptic and sensory evaluation in a room with an air temperature of 21°C, 75% air humidity, and 380 lux illumination. Before this, the products were cooled to room temperature. The external appearance of the products was determined by inspecting and developing a general opinion on the condition and color of the surface and after cutting, the color of the crumb, the quality with which it had been mixed, and its porosity. The bakedness analysis involved the evaluation of the crumb surface while pressing on it in the center of the product. The taste of products was evaluated by thoroughly chewing a piece of the product (at least 3 g) for 10 seconds and the smell – by deeply inhaling air from the undisturbed surface of the product three times.

Moisture content was measured after drying a sample to constant moisture content in the ShS-2/80-SPU drying cabinet. The samples were prepared by cutting out a 30 mm thick piece from the center of the product and removing all crust and a sub-crust layer at least 10 mm thick. Next, the samples were weighed, quickly and uniformly shredded with a hand grater, weighed a second time, and transferred into glass containers with tight-sealing lids. Empty weighing bottles with lids were weighed and placed in a desiccator for 20 minutes at 130°C. After cooling to room temperature, 5 g samples of the ground product were collected, placed into the open weighing bottles, and put into the drying cabinet for 45 minutes at 130°C. After cooling, the moisture content of the studied material was determined using the formula $W= [(m_1-m_2)/m]\cdot 100$, where m_1 is the mass of the loaded weighing bottle before drying, g; m_2 – the mass of the loaded weighing bottle after drying, g; m – the mass of the sample before drying, g. Here we should note that to the above moisture content, we also added moisture loss (W_n, %), calculated using the formula $W_n= [100\cdot(m_3-m_4))/m_3]$, where m_3 and m_4 are the mass of the sample before and after grinding, respectively, g.

A ground sample for determining acidity was prepared following the procedure described above. For the test, a 25 g sample of the ground material was collected and placed in a glass container with a tight-sealing lid and a volume of at least 500 cm^3. After this, 250 cm^3 of distilled water was poured into the container and mixed thoroughly, shaking the resulting solution periodically, then rested for half an hour and strained into a clean container. Using a pipette, two 150 cm^3 were each filled with 50 cm^3 samples of the prepared solution. After that, manual titration with sodium hydroxide solution (NaOH – 0.1 mol/dm^3) with 3 drops of phenolphthalein was performed until obtaining weak pink coloration that persisted for at least 60 seconds. Acidity in degrees was calculated using the formula

$X= [(V\cdot V_1\cdot a)/(10m\cdot V_2)]\cdot K$,

where V is the volume of the NaOH (0.1 mol/dm^3) solution used in titration, cm^3;

V_1 – the volume of distilled water used,

cm^3; a – correction factor for converting the weight to 100 g;

K and 1/10 – correction factors to bring the NaOH solution to the required parameters;

m – the mass of the ground material used in the test, g;

and V_2 – the volume of the solution collected for titration, cm^3.

The material's degree of acidity is the volume of NaOH consumed to neutralize the acids contained in the sample.

As part of the research program, we developed the formulation of experimental products where whole wheat flour was partially replaced by grape seed powder in the amounts of 0.0% for the control variant and 2.5, 5.0, 7.5, and 10% for the experimental variants (Table 1). As suggested by the preliminary studies and literature review, greater amounts of the additive in the flour mix are inexpedient due to possible deterioration of the baking and consumer characteristics of the products. The developed formulation in terms of its

Table 1. Experimental product formulation.

Name of raw material	Raw material mass, kg				
	% of phytoadditive in the weight of flour				
	0.0	**2.5**	**5.0**	**7.5**	**10.0**
Whole grain wheat flour	100.0	97.5	95.0	92.5	90.0
Grape seed powder	0.0	2.5	5.0	7.5	10.0
Dry baker's yeast	1.0	1.0	1.0	1.0	1.0
Granulated sugar	5.0	5.0	5.0	5.0	5.0
Food-grade salt	1.3	1.3	1.3	1.3	1.3
Drinking water	52.0	52.0	52.0	52.0	52.0
Vegetable oil for greasing the molds	0.20	0.20	0.20	0.20	0.20

components is characteristic of wheat bread made according to GOST 58233-2018.

Once the products were produced, their organoleptic characteristics, such as appearance and crumb condition, were evaluated (Table 2).

Data analysis**:** The data collected from the sensory evaluation and physicochemical tests were analyzed using descriptive statistics to assess the impact of varying concentrations of grape seed powder (5%, 10%, and 15%) on bread quality. To improve the reliability of the results, each treatment was replicated three times.

RESULTS

The enrichment of products with the phytoadditive directly affects the color of their surface and crumb, giving them a brown tint characteristic of grape seed powder. The powder material adds flavor and aroma characteristic of grapes to the products, the intensity of which varies depending on the amount of additional raw material added.

The impact of the grape seed powder on other indicators is no less significant (Table 3). The rich biochemical composition of the additive has had a positive effect on the activity of yeast cells, stimulating fermentation processes. We observed a combined increase in the acidity (by 3.3-15.2%), porosity (by 0.8-1.4%), and specific volume (by 2.0-5.2%) of experimental products. The finely dispersed structure of the powder material contributed 0.2-0.7% to the moisture-holding capacity of the dough.

Table 3. Physicochemical indicators of experimental products.

Indicator	Variant				
	0.0	**2.5**	**5.0**	**7.5**	**10.0**
Moisture, %	40.0	40.2	40.4	40.5	40.7
Acidity, Thorner degrees, no more than	3.0	3.1	3.2	3.3	3.5
Porosity %, no less than	69.1	69.9	70.3	70.4	70.5
Specific volume, cm^3/100 g	295	301	306	310	311

The enrichment of products with phytoadditive in the amount of 7.5% of flour weight proved the most advantageous according to the totality of evaluated indicators. This product was distinguished by balanced flavor and aroma profiles and

Table 2. Organoleptic indicators of experimental products.

Indicator	Variant				
	0.0	**2.5**	**5.0**	**7.5**	**10.0**
External appearance:					
Surface	Smooth				
Color	Light brown	Light brown	Brown	Brown	Brown
Crumb condition:					
Bakedness	Baked, not moist to the touch				
Mixing	No lumps and no traces of unmixing				
Porosity	Developed, without voids and compactions. The crust is not flaking off the crumb				
Color	White with a creamy tint	White with a brownish tint	Light brown hue	Light brown hue	Light brown hue
Taste	Corresponding to the type of product, with no unusual flavor	Corresponding to the type of product, with a hint of grape flavor	Corresponding to the type of product, with a faint grape flavor	Corresponding to the type of product, with a nice grape flavor	Corresponding to the type of product, with a distinct grape flavor
Smell	Corresponding to the type of product, with no unusual smell	Corresponding to the type of product, without a distinct foreign smell	Corresponding to the type of product, with a hint of grape smell	Corresponding to the type of product, with a subtle, pleasant grape smell	Corresponding to the type of product, smelling of grape

the most productive activity of yeast cells. The experimental product with the addition of 7.5% of grape seed powder is shown in Figure 3.

Figure 3. Experimental product.

DISCUSSION

According to expert estimates, the wine industry annually leaves 2.4 million tons of grape seeds as a by-product (Matvienko *et al*., 2022; Oprea *et al*., 2022). Grape seeds are a well-known processing material that has found its use in the production of waffles (Altinok *et al*., 2022), chocolate (Bolenz and Glöde, 2021), yogurt (El-Sayed *et al*., 2022), and other products. The content of fiber, calcium, magnesium, and potassium in grape seed powder is respectively 42, 9, 8, and 2 times higher than in flour made from wheat grain (Oprea *et al*., 2022). Combined with a significant content of other biologically active substances, this makes grape seed powder an indispensable component in functional food products.

According to Koç and Atar Kayabaşi (2023), the application of grape seed powder in dosages from 0.5 to 4% in the formulation of wheat bread had a positive result consisting in increased phenolic compound content and improved antioxidant activity and elasticity.

Considerable improvement of the porosity of bakery products when using grape seed powder is explained by its significant effect on the fermentation activity of yeast cells, provided by the high content of phenolic and flavonoid compounds, specifically 1.352 g of gallic acid and 0.227 g of rutin per 100 g of powder (Grinvald *et al*., 2024).

No less interesting are the results of comparative studies on the effects of grape skin and grape seed powders (in dosages from 0 to 15% of the weight of flour) on the rheology of wheat flour dough. These materials reduced the crumbliness of the products and improved their digestibility (Kuchtová *et al*., 2018). Unlike grape skin powder, grape seed powder significantly enhanced dough stability.

Similar results on the influence of grape seed powder on dough were obtained in other studies (Elkatry *et al*., 2022). The incorporation of the grape additive into the formulation in dosages of 5, 10, and 15% of wheat flour actively increased water absorption by the flour mix. The optimal dosage for the enrichment of the flour mix was 10%. The respective product was marked by a significant content of polyphenolic, flavonoid, and antioxidant compounds.

Scientific sources also report some deterioration of the baking qualities of dough and the organoleptic characteristics of products when adding grape seed powder. Nevertheless, researchers note that despite the drawbacks discovered with the addition of 7 and 9% of the additive, the enrichment of wheat bread with 3 and 5% of the additive is promising in terms of increasing the content of fiber, copper, and zinc (Oprea *et al*., 2022).

Of note is the experimentally confirmed positive experience of using grape seed powder in the composition of flour mixes, for instance, combined with first-grade wheat flour, flaxseed flour, and hemp seed flour. The addition of 5% grape material from the total mass of the flour mix led to a significant improvement in the organoleptic, physicochemical, and consumer characteristics of the products (Merenkova *et al*., 2021).

Our findings correlate with available research data and substantiate the expediency of using grape seed powder in bread making. Existing differences in the effects of different doses of the raw material used might also owe to the varietal characteristics of grapes, their growing conditions, and the vinification process, which in their totality determine the biochemical composition of the fruit and its seeds (Abouelenein *et al*., 2023).

Conclusion: Our study highlights the potential of grape seed powder as an innovative ingredient in bread production. By partially substituting whole wheat flour with grape seed powder, we developed the formulation of a prospective bakery product combining valuable biochemical and technological characteristics of whole-grain wheat flour and grape seed powder. Our results showed notable improvements in the nutritional profile and the physicochemical properties of the bread.

The most optimal dosage of the phytoadditive (grape seed powder) was 7.5% of the mass of flour, resulting in a balanced enhancement in flavor, aroma, porosity, and specific volume, alongside an increase in the bread's moisture-holding capacity and acidity.

This study sets a strong foundation for leveraging the untapped potential of agricultural by-products by reinforcing the importance of innovative approaches to food production that benefit both the industry and the environment. Our study agrees with the current global perspective on zero-waste technologies and effective resource management. It also highlights the potential of agricultural by-products, like grape seeds, in the food industry. By converting grape seed waste into functional phytoadditives, we can contribute to sustainable practices and support nutritional improvement by incorporating essential nutrients such as fiber, magnesium, calcium, and antioxidants into our daily diets and aligning with the health requirements for consumer goods. The successful incorporation of grape seed powder into bakery products paves the way for its potential use in other food formulations, such as composite flour mixes and other functional foods.

We recommend that future research expand on the compatibility of grape seed powder with different types of flour and other baking ingredients for the comprehensive enrichment of bakery products, increasing their functional, therapeutic, and prophylactic characteristics. Additionally, more research should be directed to the long-term consumer acceptance, shelf life, and health impacts of these enriched products so as to further validate their practical applicability.

Authors' contribution statement**:** Conceptualization, A.V. and I.K.; Methodology, A.V., E.C.; Formal Analysis, E.C.; Investigation, V.G.; Resources, E.C.; Data Curation, I.K.; Writing – Original Draft Preparation, A.V.; Writing – Review & Editing, V.G.; Visualization, V.G.; Supervision, I.K.; Project Administration, V.G.

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Ethical statement**:** No formal ethical approval was required for this study.

Availability of data and material**:** The data generated during this study, including experimental results and the bread formulations, are available with the corresponding author and will be available on reasonable request.

Informed consent**:** N/A

Consent for publication**:** The authors have obtained consent from all relevant parties for the publication of this study.

SDGs addressed**:** Zero Hunger, Responsible Consumption and Production, Good Health and Well-being.

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