Pea Germ Powder as Ingredient of Fortified High-Grade Wheat Flour Bread

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Abstract. Bakery and pastry based on high-grade wheat flour have poor biological value whilst being highly calorific; this calls for adjustment in their chemical composition. Grain processing waste including pulp, germs, bran, husks, etc., are promising materials that could be used to enrich foods with indispensable components. This paper presents a technology of baking bread with pea germ powder along with evidence-based recommendations on the quantity and method if admixing germs to dough. Evidence suggests that adding pea germ powder to high-grade wheat flour improves its biological and nutritional value and helps expand the range of fortified foods.

1. Introduction
High-grade wheat flour for baking is made of finely ground particles of central endosperm extracted from wheat grain. Such flour has ash content of ≤0.55%, raw gluten content of ≥28.0%, and fiber content of 0.10 to 0.30%. High-grade flour is rich in starch and poor in protein and vitamins [1, 2]. Essential amino acids are less abundant in comparison to other grades of wheat flour [3].

This is why bakery based on high-grade wheat flour has low biological value whilst being highly calorific, which calls for adjustments in the chemical composition [4]. It is of relevance to find raw materials to enrich high-grade wheat flour with indispensable components, and to implement a technology to make use of such materials.

2. Relevance
Almost all grain processing waste contains valuable materials that could be made into sellable products [5]. As of today, recycling rates in the food industry are about 20% to 30% [6]. However, integrated utilization of raw materials could significantly lower the costs of waste disposal [7, 8].

Creating new combined foods based on recycled plant products and devising resource-saving technologies to make new products based on available and cheap sources of plant proteins are high-priority areas of research and development towards eco-friendly food production [9].

Grain germs are richer in protein than virtually any other plant product, making them a promising recycled material. Germs contain various forms of non-protein nitrogen (10.0% to 15.3% of total nitrogen), including asparagine, allantoin, betaine, choline, glutathione, and nucleic acids (3.5% to 4.2%).

Germ proteins are of high biological value. Germs are also richer in lysine than some animal products that provide this amino acid in human diet [10]. It is also the richest part of the grain in terms...
of lipid content: 8.0% to 27.6% [11]. The carbohydrate complex mainly consists of sugars. Germs also contain all enzymes typical of living plant cells and enabling specific functions of biochemical metabolism processes. Lipase is one of the crucial germ enzymes. Legume seeds top the ranks in terms of lipoxygenase activity.

Being of high nutritional and biological value, germs could be used as an additional ingredient in novel bakery products, pastries, or pasta designed as functional or therapeutic foods [12, 13]; they could also be used as a protein filler in fermented dairy [14]. Available data suggests foods with grain germs help prevent dysbiosis and cardiovascular disease, support normal intestinal microflora, prevent colon cancer, and strengthen immunity [15, 16].

3. Formulation of the problem
Bread whose ingredients include pea germ powder has better nutritional and biological value; the technology behind it will expand the range of bread that could be baked from high-grade wheat flour.

It will also address the issue of recycling pea processing waste and expand the range of raw materials for producing fortified foods.

4. Theoretical part
Pea germ powder was used as an additional ingredient for making fortified bread. It is essentially finely ground flour of pea germs, variety Temp; the germs are a byproduct of making starch from peas [17].

Pea soaking activates enzymes, which enhances the germs with a biologically active protein complex, peptides, free amino acids, lecithin, soluble sugars, fiber, macronutrients and micronutrients, vitamins, and phytohormones [18].

Pea germ powder is 50.97% protein, 11.75% sugars, 4.93% fiber, 4.93% lipids as well as vitamins B₁, A, E and minerals Ca, P, and Mg [19]. Germ protein is complete in such essential amino acids as threonine, leucine, tyrosine, phenylalanine, and lysine. The lipid complex mainly consists of unsaturated fatty acids (83.8% of the total fatty acids). The presence of lipids and free fatty acids is what makes the germ powder highly acidic (TAN = 22.0).

Ungerminated peas have high concentrations of antioxidants and low peroxidation of lipids as well as low peroxidase activity [20]. Lipid peroxidation activates as they swell and germinate. Intensified breathing alters the germ components. It affects the composition of antioxidants and boosts the activity of enzymes that control hydrolytic and oxidative processes. Pea germ powder, variety Temp, has traces of water-soluble antioxidants, lipoxygenase, and antioxidant enzymes: peroxidase, catalase, and ascorbate oxidase.

5. Results of experimental studies
The authors hereof proposed two recipes of high-grade wheat flour enhanced with pea germ powder; such diversification was required due to the chemistry of this powder.

Recipe 1: mix together warm drinking water, pressed baker’s yeast, table salt, sifted mixture of germ powder and high-grade wheat flour.

Recipe 2: dissolve pressed baker’s yeast and table salt in warm water, admix a portion of sifted high-grade wheat flour and sifted germ powder. Stir the resulting suspension intensely. Then add the rest of the high-grade wheat flour, see Fig. 1.
The dough was kneaded intensively and left for 170 minutes in a fermentation chamber, re-kneading after 60 minutes and 120 minutes of fermentation. Fermented dough was cut into pieces and left in a thermostat for 45...50 minutes for proofing, then baked at 220...230°C over 26 minutes to make hearth-baked bread, 28 minutes for mold-baked bread. Once baked, the top crust was moistened with water, and the loaves were cooled down.

The experiments produced four samples of bread per recipe, with 0.5%, 1.0%, 1.5%, or 2.0% of wheat flour being replaced with germ powder. High-grade wheat flour bread baked per GOST 27669-88 was used as control. Freshly baked bread was left to cool down over 4 hours before quality testing.

Germ powder-fortified bread had more vividly-colored crust. Suspension-based bread had brighter crumb; samples that contained 1.5% or 2.0% of the powder had purely white crumb. 2.0% samples of the mixture bread had less elastic crumb. Pea germ powder-fortified bread had 0.5% to 3.6% less moisture than the control, a sign of weaker moisture retention.

However, Recipe 2 produced 0.3% to 1.4% moister bread than Recipe 1. Apparently, intensive kneading of the powder-flour mixture helped retain moisture. Using more germ powder was associated with higher acidity, as the powder itself is acidic; none of the samples exceeded the standardized safety limits. Recipe 1 produced 2.1%-20.3% less porous mold bread or 0.8%-4.3% less porous hearth bread, as adding the germ powder directly to flour reduced the gassing.

Table 1 shows the physical and chemical indicators of suspension-based bread. Bread where 1.0% of high-grade wheat flour had been replaced with pea germ powder had the best quality.

Chemical assays showed that compared to the control, 1.0% germ powder bread had 10% more protein, 4.9% more lipids, 14.0% more monosaccharides and disaccharides, 30.0% more fiber, 2.4% more ash, and 5.0% vitamin B1. It also had 1.2 kcal less than the control due to being poorer in starch.
Table 1. Physical and chemical indicators of bread quality of pea germ powder-fortified bread.

| Indicator                        | High-grade wheat bread (control) | High-grade wheat bread, % replaced with pea germ powder |
|----------------------------------|----------------------------------|--------------------------------------------------------|
| Moistness, %                     | 42.0±0.1                         | 41.5±0.2, 40.9±0.1, 40.3±0.1, 39.8±0.1                |
| TAN                              | 1.8±0.0                          | 1.8±0.1, 2.1±0.0, 2.2±0.1, 2.4±0.1                    |
| Porosity, %:                     |                                  |                                                        |
| mold-baked bread                 | 73.1±0.2                         | 70.3±0.1, 74.2±0.2, 73.0±0.2, 68.1±0.1                |
| hearth-baked bread               | 73.2±0.1                         | 74.4±0.2, 74.8±0.2, 71.1±0.1, 68.4±0.1                |
| Specific volume, cm$^3$/kg:      |                                  |                                                        |
| mold-baked bread                 | 3.1±0.1                          | 2.9±0.1, 3.2±0.1, 3.0±0.2, 2.9±0.1                    |
| hearth-baked bread               | 3.2±0.1                          | 3.2±0.2, 3.4±0.1, 3.3±0.2, 3.0±0.1                    |
| Shape stability (H/D)            | 0.93±0.01                        | 0.76±0.02, 0.86±0.02, 0.78±0.01, 0.74±0.02            |

The resulting product was also richer in sodium, calcium, phosphorus, and magnesium than the control, see Fig. 2.

![Figure 2. Macronutrients and micronutrients in pea germ powder-fortified bread.](image)

It was also richer in total amino acids: +13.4% essential acids and +1.0% amino acids in general. The recipe boosted the content of threonine, isoleucine, and lysine by 87.6%, 51.6%, and 30.7%, respectively.

6. Conclusion
Making a suspension is the best way to add pea germ powder to dough based on high-grade wheat flour. Intensive stirring of dough components mixed with the germ powder and a portion of wheat flour saturates the dough with air oxygen, which lipoxygenase in the powder uses to produce hydroperoxides of unsaturated fatty acids. This improves the structural mechanical properties of the dough and lightens up the crumb [3]. Increased water absorption capacity of the dough facilitates gelatinization, improves the quality of crumb, and helps the dough rise higher [21]. Applying the additive at the yeast activation boosts the reproduction of yeast cells by enriching the nutrient medium with vitamins, sugars, amino acids, and minerals.

Thus, using pea germ powder when baking bread from high-grade wheat flour increases the content of protein, lipids, carbohydrates, macronutrients and micronutrients, vitamin B$_1$, and essential amino acids.
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