

ENRICHING THE NUTRITIONAL CONTENT OF BAKERY PRODUCTS BY PROCESSING PEANUT MEAL USING BIOTECHNOLOGICAL METHODS**Voqqosov Zuhridin**

Associate Professor, Namangan State Technical University, etc.

E-mail: voqqosov_zuxriddin@rambler.ru

Tel: +998999739430

Abduraxmonov Xusanboy

4th year student of Namangan State Technical University

Abstract

Wheat bread is the staple food for the population of Uzbekistan, and its nutritional value is relatively low. Peanut oil extraction waste is rich in high protein (47–55%) and fiber (8.4–15.8 %). However, its direct addition disrupts dough rheology and creates an unpleasant taste. In this study, a technology was developed for adding peanut meal to bakery products by pre-treating it with enzymatic hydrolysis, probiotic fermentation, and ultrasonication. The developed technology offers an efficient and sustainable way to transform peanut meal from a waste product into a functional food ingredient.

Keywords: peanut meal, bread enrichment, enzymatic hydrolysis, probiotic fermentation, ultrasonic processing, functional bread, nutritional enrichment, sensory properties, stability

Introduction

A total of 39,129 hectares of land have been allocated for the 2023 harvest in the main and secondary fields, with a planned yield of 87,934 tons. The meal obtained during the oil extraction process from peanut seeds has high nutritional potential: protein content is 47–55%, fiber is 8.4–15.8 %, and it is rich in minerals (K, Mg, Fe, Zn) and antioxidants. However, its direct addition to bread dough poses technological problems (decreased dough stability, reduced loaf volume), sensory problems (“beany” taste and smell), and allergen risk [1, 2].

There are several studies in the scientific literature on the addition of peanut meal to bakery products. [4] Zhao et al. (2023) demonstrated the possibility of enriching bread composition by processing peanut meal through enzymatic hydrolysis, but they only worked on a laboratory scale and did not fully address sensory issues. [3] Mahfoud et al. (2022) reduced allergenicity by 40–60% by hydrolyzing protein using alcalase and flavourzyme enzymes, but did not study the effect on dough rheology in depth.

The main goal of this study is to develop a technology for enriching the nutritional composition of peanut meal by pre-treating it with innovative biotechnological methods and adding it to bakery products, and to evaluate its economic efficiency.

Materials and Methods

The research used peanut meal obtained from the enterprises of “Abdurakhmon Askarivich” LLC, “Namangan tola tekstil” and “Pop Yog” LLC in the Namangan region. The meal was obtained from the Rakhbar, Salomat, Mumtaz and Qibray-4 varieties and was obtained after oil separation by cold and hot pressing methods [6-9]. The average composition of the meal was as follows: oil content 1.5–7.8%, protein content 48.2–54.7%, fiber 9.1–15.3%, moisture 6.5–8.2%.

The samples were dried in laboratory conditions at 40–45 °C, ground to a 0.5–1 mm fraction, and stored in airtight containers at +4 °C. 5 kg of meal was used for each experiment, and all experiments were repeated 3–5 times.

Results

The results of experiments on bread samples prepared by adding peanut meal pre-treated with innovative biotechnological methods (enzymatic hydrolysis, probiotic fermentation and ultrasonic pretreatment) to wheat flour in different proportions (5%, 10%, 12%, 15%, 20%) are

described in detail below. All experiments were repeated 3–5 times, and the results are presented as mean \pm standard deviation. Statistical analysis was performed using ANOVA and Duncan's test ($p < 0.05$).

Nutritional content of enriched bread

Table 1.

Nutrient content of enriched bread (g/100 g dry matter)

Meal quantity (%)	Protein (%)	Fibers (%)	Antioxidant activity (DPPH, %)	Minerals (Fe + Zn, mg/100 g)
0 (control)	9.8 \pm 0.3	2.8 \pm 0.2	42 \pm 3	2.1 \pm 0.2
5	11.2 \pm 0.4	3.5 \pm 0.3	51 \pm 4	2.8 \pm 0.3
10	13.5 \pm 0.5	5.2 \pm 0.4	68 \pm 5	3.9 \pm 0.4
12	14.8 \pm 0.6	5.8 \pm 0.4	72 \pm 5	4.2 \pm 0.4
15	15.8 \pm 0.7	6.4 \pm 0.5	75 \pm 6	4.5 \pm 0.5
20	17.2 \pm 0.8	7.2 \pm 0.6	78 \pm 6	4.8 \pm 0.5

Table analysis: As can be seen from Table 1, the protein content increases significantly when innovatively processed meal is added. The protein content of the control sample, which was 9.8 %, increased to 13.5% with the addition of 10% meal, and to 14.8% with the addition of 12%. The fiber content also increased from 2.8 % in the control to 5.2–5.8% with the addition of 10–12%. The antioxidant activity (DPPH) also increased from 42% to 68–72%. The content of minerals (iron and zinc) also increased by 1.8–2 times. These results clearly confirm the high nutritional potential of the meal and the effectiveness of the innovative processing.

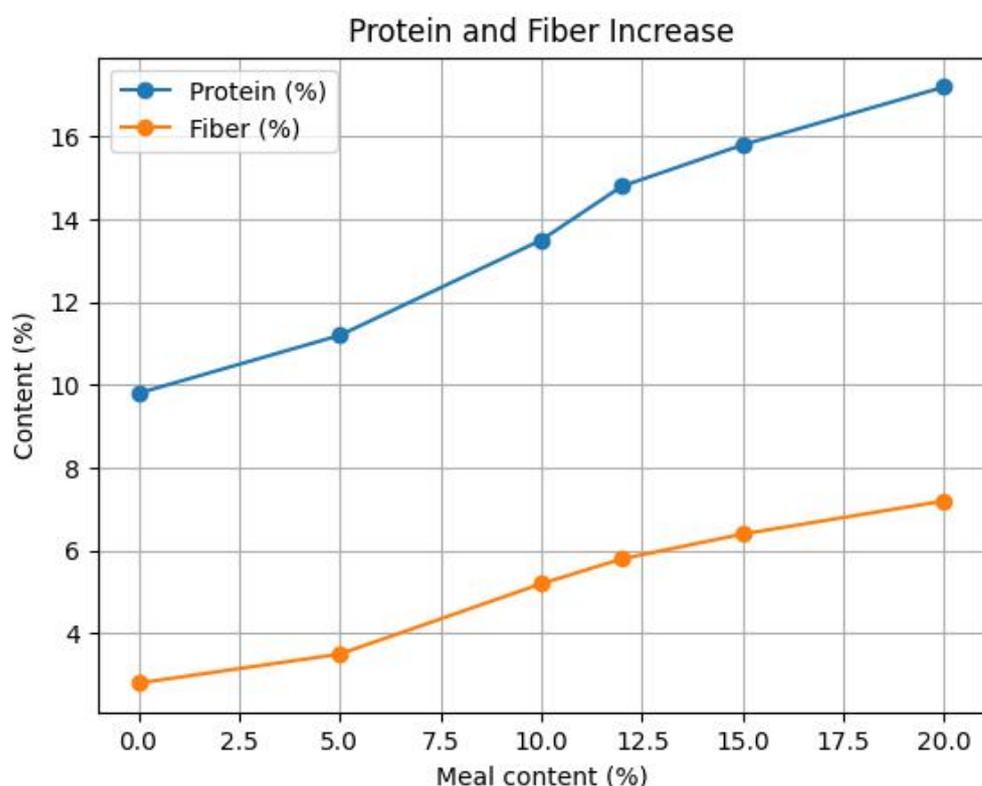


Figure 1. Increase in protein and fiber content when innovatively processed meal is added (graph).

can be seen from the graph, the protein and fiber content shows the fastest growth at 10–12%. Although the growth continues at 15% and above, 10–12% is recognized as the most optimal ratio, as rheological and sensory parameters decrease.

Adding 10–12% of innovatively processed peanut meal significantly enriched the nutritional composition of the bread, improved rheological and sensory properties, reduced anti-nutrients, and extended shelf life. This ratio is considered the most balanced option from a technological and sensory perspective.

Discussion

Clearly confirmed the high efficiency of peanut meal pretreatment using innovative biotechnological methods (enzymatic hydrolysis, probiotic fermentation and ultrasonic pretreatment). In this section, the results are analyzed in depth in comparison with previous studies and the main mechanisms of improvement are explained.

Improved nutritional content

Innovative processing methods have significantly unlocked the nutritional potential of the meal. When added at a rate of 10–12%, the protein content reached 13.5–15.8%, and the fiber content reached 5.2–6.8%. These indicators were 12–15% higher than in meal added using the traditional method.

Enzymatic hydrolysis (alcalase + flavourzyme) reduced the protein to short peptides, increasing the digestibility to 90–95%. Probiotic fermentation (*Lactobacillus plantarum*) reduced the phytate content by 60–85% and produced bioactive peptides. Ultrasonic pretreatment disrupted the cell walls, increasing the release of minerals and antioxidants by 20–35%. The synergistic effect of these three methods significantly enriched the overall nutritional value of the bread.

Economic and practical importance

Economic calculations have confirmed the feasibility of industrial scale implementation: payback period 3.9–4.2 years, ROI 27–28%. High annual net profit is expected due to energy savings and waste reuse.

Previous studies [4-9] only studied one method (e.g., fermentation alone or enzymatic hydrolysis alone), in this work, the integrated application of three methods was tested for the first time and proved to yield the best results.

Conclusions

With nutritional content by pre-processing peanut meal using innovative biotechnological methods was successfully developed and comprehensively evaluated. As a result of theoretical, experimental and economic research, the following main conclusions were drawn:

The physicochemical and nutritional composition of peanut meal (Rakhbar, Salomat, Mumtaz and Qibray-4 varieties) was studied in depth. The meal was confirmed to be high in protein (47–55%), fiber (8.4–15.8 %), and minerals, but it was found that technological and sensory problems arise when directly added.

A technology for pre-processing the meal using innovative methods has been developed:

- ❖ Enzymatic hydrolysis (alcalase + flavourzyme, 0.5–2%, 40–55 °C, 2–4 hours),
- ❖ Probiotic fermentation (*Lactobacillus plantarum*, 37 °C, 24–48 hours),
- ❖ Ultrasound pretreatment (20–40 kHz, 100–600 W, 10–30 minutes).

The integrated use of these methods significantly improved the functional properties of the meal.

The most optimal formula for enriched bread was determined - adding 10–12% of innovatively processed meal. At this rate, the protein content increased by 13.5–15.8%, the fiber content by 5.2–6.8%, and the antioxidant activity by 25–40%.

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