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Rice-Legume Flour as an Alternative to Gluten-Containing Flour in Bread Baking

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Abstract

The article describes the development process of a new product - rice bean flour bread. The product is a functional alternative to classic wheat flour bread. The development of the new product is based on literature research and experiments. The ingredients of alternative flour bread are characterized. The most difficult thing in the development of alternative flour bread is the imitation of gluten, in connection with which gluten alternatives are studied. For its imitation, such groups of raw materials as hydrocolloids and proteins are offered. Conclusions are drawn about the importance of ingredients in alternative bread and the possibilities of gluten imitation. Bread made with just rice flour was crumbly, dry, and had a bad texture. Although adding potato starch decreased crumbling and increased cohesiveness, it also added an unwanted aftertaste. Tapioca starch lessened the aftertaste of potato starch and enhanced texture. Using eggs as a source of protein enhanced crumb structure and bread growth.

Keywords: alternative flour, alternative flour bread technology, bread, home production

1. Introduction

One of the main sources of carbohydrate extraction in the human diet is bread. Bread is not only a basic element of the nutritional pyramid, but also an important symbol in Latvian culture. Bread is a product with a rich history. It is a symbol of respect and prosperity, brought to the table at any meal, so it has always been a topical product.

Consumers are more likely to appreciate the healthiness aspect of food products. Primarily, the choice of buyers between products that are products of the same category is influenced by price, but the results of studies show that the impact of a product on the health of the consumer and the environment does not lag far behind the price as an influencing factor. (Grivin, 2023) Due to the fact that people are starting to think more often about their health and the well-being of the planet, the number of vegetarians in the world is increasing. For vegetarians, protein is an important group of nutrients, since excluding meat from the diet excludes a significant source of protein. (Dulman, n.y.) Legumes are considered an excellent source of protein and an analogue of meat, in connection with this, the importance of proteins from legumes and oilseeds in the production of various functional foods is growing, since they have a high protein content (Kumar, 2016).

2. Materials and Methods

The development of the new product is based on literature research and experiments. The goal is to develop a product - an alternative to classic wheat flour bread, which does not contain yeast, dairy products, naturally gluten-containing products, sugar. Since naturally gluten-containing products are excluded in the development of the new product, information that is relevant to gluten-free products is initially selected. However, the product is not positioned as gluten-free. By studying the literature, several main potential ingredients are identified and characterized, with which experiments are conducted. During the experiments, the final ingredients for the new product - alternative flour bread are determined.

Selection of alternative raw materials for flour bread, characteristics.

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When determining raw materials, it is primarily necessary to find out what alternative flour is. Initially, the author defines alternative flours: flours that are naturally gluten-free. Alternative flours can include flour such as: buckwheat, quinoa, amaranth, corn, rice, sorghum, millet. (Šmídová et al 2022). Alternative flour mixtures usually contain a mixture of starch, water-soluble polysaccharides and rice flour, which are more neutral, light and tender in taste, they have more easily digestible carbohydrates. (Ren, 2020). The study of the literature is also attributed to gluten-free production, since the main difference between gluten-free and alternative flour bread is the presence of gluten-free cross-contamination, which is not permissible in gluten-free production, but is permissible in alternative flour bread.

The biggest challenge in developing alternative flour bread is the imitation of gluten, which is a wheat protein, since it plays an important role in the preparation of any flour product, so its role in bread is being studied. Gluten proteins form a continuous network in the dough. This net ensures the unity, bonding of substances, as well as the viscous elasticity of the dough, which is necessary for the preparation of bread. (Shewry, 2019) The absence of gluten in gluten-free production resulted in bread with poor texture and colour, characterized by a smaller specific volume. As well as such bread has a shorter shelf life, great dryness, unpleasant taste. The volume of such bread is often less. (Capelli et al., 2020) Gluten plays an important role in tying water into the product. This eliminates such adverse properties as crumbling and dryness. The gluten network contributes to the retention of gases in the product, which, in turn, increases the volume of the product. (Capelli et al., 2020) To create a successful alternative flour bread, it is necessary to find a substitute for gluten. Given that gluten provides several quality-enhancing properties to a product, it is not possible to replace it with just one ingredient. Hydrocolloids and proteins are cited as the main substitutes for gluten. (Arendt et al., 2008a), (Arendt et al., 2008b).

Hydrocolloids are polysaccharide polymers. Their main property is the ability to absorb and retain water in the product, as they are hydrophilic. In the food industry, they are usually used as thickeners and gelling agents. These can include resins, starches, pectin, agar-agar. (sperohope.com, 2025) Their high-water binding capacity means that they can provide stability to products undergoing freezing-thawing processes. (Capelli et al., 2020) In many literary sources it is mentioned that hydrocolloids are used in the production of gluten-free bread, as the main and most widespread is psyllium. Psyllium is a natural source of fibre; it is insoluble in water. This creates the effect of a clinging gel in the product. (Ren, 2020)

Starch is a unique carbohydrate of plant origin, as it is naturally present in the form of dense and relatively insoluble, semi-crystalline granules. Starch is a water-insoluble polysaccharide. It plays several roles in the processing of food products. It affects the rheology and stretchability of the dough, the texture of the bread. Heating of starch suspensions in water leads to changes at the molecular level, as a result of which crystallinity decreases and starch granules irreversibly swell. This process is called gelatinization. Gelatinization is also associated with a decrease in starch dissolution, which determines an increase in the viscosity of the starch suspension. Gelatinization of starch can be provided only if there is enough water. (Capelli et al., 2020) During heat treatment, starch wanders in the presence of water, but without the presence of water, it turns into dextrin's, which gives the products a brown colour. (Gavrilenko, 2001)

When starch is cooled after heating, another phenomenon occurs, which is called retrogradation. Here, starch polysaccharides are associated again, forming a more orderly, crystalline state. Retrogradation is influenced by several factors. The most notable are associated with the presence of other molecules, such as sugars, salts, lipids. (Capelli et al., 2020)

There are several sources of starch that do not naturally contain gluten. These include rice, potatoes, tapioca and cornstarch. Potato starch is the most promising, as it has desirable properties that are significantly different from other starches. A small amount of potato solids helps to preserve the freshness of the bread and gives it a characteristic, pleasant taste, improving the taste characteristics. The study also notes that high molecular weight amylose and phosphate groups esterified to amylopectin contribute to the high transparency, swelling, water-binding ability and freezing and thawing stability of potato starch. (Capell et al., 2020)

Tapioca starch (also called cassava starch) is referred to in the scientific literature as starch, which produces the most acceptable indicators for gluten-free bread. When comparing starch, cassava-sorghum and rice-sorghum bread have better crumb properties than corn-sorghum or potato-sorghum bread. The formula, which contains 50% cassava starch, retains the best overall texture. Potato and cassava starches are classified as starches with high swelling, as they have a weak intermolecular bond and are easily gelatinized, forming a mass of high viscosity. (Onyango et al., 2011) Tapioca starch granules are slightly larger than corn and range from 7.1 to 25.0 μm. Starches differ in the shape and size of the granules, ranging from large (potatoes) to small (corn and tapioca) and oval (potatoes) to multifaceted (corn) or spherical with some shortened (tapioca) granules. Small grooves were also observed in some tapioca starch granules. It is observed that the pH of tapioca is lower (4.80) than that of corn and potato starch, whose values: 6.24 and 7.15, respectively. Among corn, potato and tapioca starch, tapioca starch has the lowest degree of whiteness, 87%, while corn starch, for example, has 99%. Tapioca starch has a lower amylose content, 16.27%, while corn starch has a 25.60%. Also, the moisture content of tapioca starch is lower -7.54% than

that of potato or corn starch. Potato and tapioca starch have a lower lipid content than corn starch. The increase in solubility at high temperature (70 °C) is more for potato and tapioca starch. Since tapioca starch has a lower content of amylose, then it gels in a higher concentration compared to potato starch. Tapioca starch jelly is softer, less elastic, resinous and chewable compared to potato and corn starch. Tuber and root starch contains a lower content of proteins, lipids and ash than cereal starch. (Mishra et al., 2006)

Xanthan gum, also known as bean resin, is a polysaccharide with a wide range of applications. It is obtained by fermentation of sugars or small polysaccharides (various starches) using the bacterium Xanthomonas campestris. It is a very popular ingredient in gluten-free products to obtain a dough consistency that is more like gluten-containing products. Food is usually used in concentrations of up to 0.5 % (Lerochem.eu.). The addition of xanthan gum to the dough leads to the greatest increase in viscoelasticity modules and the lowest hardness of the bread. Of the hydrocolloids, they have the highest water-retaining ability. They increase the elasticity of the dough and the viscosity, consistency and strength of the dough, increase the strength of the gas cells in batters made with rice, corn and buckwheat flour. Bread with xanthan gum has a larger specific volume, reduced hardness of crumbs, improved colour, larger gas cells and improved porosity of the crumbs, increased moisture content, reduced water loss, improved sensory perception. The addition of xanthan gum gives the highest results of elasticity and resistance of the dough to deformation. (Capelli et al 2020) Gel formation or an increase in the viscosity of the solution is a frequent result of the interaction of xanthan resins in solutions (Larrosa et al., 2013).

In gluten-free production, both animal and plant products, such as legumes, eggs, etc., are used to provide protein. Like other improvers, the purpose of adding protein is to strengthen the structure of the dough. An additional benefit is the improved nutritional content. (Capelli et al., 2020)

Egg albumins have a relatively small molar mass and high absorption abilities of carbon dioxide, which is significant in the process of its binding. An important factor that has a positive effect on the volume of loaves is the low denaturation temperature of albumin, which is responsible for the formation and stabilization of the structure during frying. (Ziobro et al., 2015)

Legumes are a source of protein that has been widely studied in the literature. One study emphasized that the addition of lupine and pea protein isolates improved dough rheology, increased loaf volume, cell pores, and produced softer crumbs. (Horstmann et al., 2017) Lupine protein reduces the hardness of the crumbs and slightly increases the storage module. (Ziobro et al., 2015)

Chickpea protein is recognized as an excellent improver of the dough. The addition of 5% chickpea flour significantly improves ancient wheat flour, in terms of increased stability of the dough and the volume of bread. (Capelli et al., 2020) Chickpeas have proven to be able to enhance gluten-free dough and bread. (Capelli et al 2020)

Beans have a low glycemic index and, as a result, can raise blood glucose levels after eating at a relatively low level. (Wesley et al 2021) The moisture content of legume flour ranges from 7.9% to 10.8%. (Wilman, 2015) White beans are the most important nutritional legume in many countries around the world. It has a high content of protein, dietary fibre and minerals. Bean protein is rich in lysine. Beans are an important source of minerals such as iron, phosphorus, magnesium, manganese and vitamins A, C, E, K and PP, vitamin B and folic acid, as well as soluble and insoluble dietary fibre, which have a beneficial effect on health. Bread made with bean flour; the water absorption capacity of the dough increases with the increase in bean flour. (Hoxha et al., 2020)

Water is an important source of life, which is involved in the production of almost every product. It, by its chemical structure, is a very universal substance. Water is the basis of chemical reactions. Water is a very important ingredient in a large part of products, including gluten-free products, just as its absorption is of great importance. Water affects the structure, taste of bread also in volume and baking processes. (Capelli et al 2020) The amount of water determines the consistency of the dough and affects its fermentation. It plays a key role in the gelatinization of starch. Most gluten-free bread has a higher water level, and the dough has a more liquid-like structure. Less hydrated gluten-free doughs have less ability to retain the gases released during fermentation, while highly hydrated doughs need to be fermented longer, improving the specific volume. (Capelli et al., 2020)

As substitutes for basic wheat flour in scientific publications, rice flour, cornmeal or buckwheat, amaranth flour are mentioned. (Capelli et al 2020) But an evaluation of the literature leads to the conclusion that rice is mentioned more often as a base ingredient, so rice flour is being studied. It has been proven that in combination with starch and an appropriate hydrocolloid, rice flour is suitable to produce gluten-free bread. Breads with rice flour form even, elongated pores with thin walls. (López et al., 2004) When comparing rice flour produced from two different rice varieties, Basmati and Bomba, with amylose lengths of 699 and 978, Basmati rice flour produces a harder crumbly texture than Bomba, with no significant differences in amylose content. The study concludes: the length of amylose is a decisive factor affecting the quality of rice bread. (Ronie et al,.2022)

Although salt is added to batters in small quantities (1.2-1.8% of the amount of flour), it plays an important role in the preparation of bakery products. It improves the properties of the dough, regulates the fermentation processes and affects the taste of bread. The dough without salt is sticky, fuzzy, rapidly ferments and does not hold its shape, the bread has a pale, hard crust and a flabby taste. An excessive amount of salt (above 2% of the amount of flour) in the dough delays the fermentation processes, sometimes the dough does not ferment at all, it is wet, difficult to process, but the products have an unpleasantly salty taste. In the production of bread, different types of salt can be used – coarse, fine, vacuum salt, fluorosal or iodal. (Latvian Rural Advisory and Education Centre.)

Fat. Gluten-free bread is characterized by a higher fat content than gluten-containing bread. (Tres et al., 2020) Many industrial manufacturers use cheap vegetable fats such as palm or palm kernel oil to produce gluten-free products, but local producers are inclined to use quality vegetable fats, such as olive oil. (Maggio et al., 2018) Among the most used oils in gluten-free breads are sunflower oil and olive oil. Olive oil is characterized by a higher content of oleic and lower linoleic acid compared to sunflower oil. Also, phytosterols by composition in sunflower oil are more than in olive oil, but there are more of them in olive oil than in coconut oil. (Tres et al., 2020) The main ingredients in olive oil, which have healthy properties, are triterpene dysalcohols and acids, squalene, tocopherols, sterols, fatty alcohols and phenolic compounds. The refining process significantly reduces the content of phenolic compounds, while the rest of the smaller components remain in concentrations that can have a positive effect on health, especially cardiovascular health. (Mateos et al 2019) Adding oil to bread dough increases its specific volume and volume. (Mokar et al., 2022) As well as oil can increase the humidity of bread and reduce acidity and brittleness. (Evlash et al., 2019)

3. Results and discussion

When evaluating potential ingredients, experiments are conducted to develop the new product. Initial experiments are carried out with a minimum amount of raw materials, evaluating the characteristics of each raw material. During the process, several experiments are conducted, but those during which there is a strong progress in the development of a new product are characterized.

The purpose of the first experiment is to test what properties rice flour has. The following are taken as raw materials: water, rice flour, rice starter, salt, linseed, baking powder. The result of the experiment is shown in Fig. 1. and Fig. 2.

Fig. 1. Rice bread from above.

Fig. 2. Rice bread in cross section.

In the Fig.1 we can see that the dough lacks binders, the bread bribe is very cracked, which indicates that its crumb, which will also confirm when cutting it. Figure 2. shows that the bread does not stick together when it is cut, especially in places where there are cracks. The flesh itself for bread, when eaten, seems dry. The bread is dense, it has practically no pores. The author concludes that rice flour alone forms an unstable product that is stirring. It is necessary to add to the present raw materials that would bind the product.

In the next experiment, potato starch is added to the raw materials and linseed is removed, since the need to include them in the recipe is not observed. This is an important experiment, since this product is already beginning to resemble bread more and is more acceptable in terms of taste.

Fig. 3. Rice bread with starch in cross section.

By the cross-section of rice bread, it can be judged that now it does not crumble so much, pores have appeared that are not pronounced but are. The flesh is soft, when tasted, a slightly wandering sensation in the mouth occurs, and there is also an aftertaste of potato starch. In general, the bread resembles more something queer.

Fig. 4. Rice bread with starch from above.

On the outside, on the other hand, the bread is light brown, the crust is not thick, it is more like shortbread in consistency. The author marked a drawing before baking bread in the dough to be sure of the properties of the dough. It is concluded that during baking, the dough expands minimally, its fluidity is low, since the drawing has largely survived. This bread hardens quickly.

In the next experiment, protein sources are compared, and tapioca starch is added to reduce the aftertaste of potato starch. Lupine flour and egg are chosen as sources of protein. Fig.5 on the left shows bread with lupine flour, Fig. 6 on the right shows bread with egg.

Fig. 5. Bread with lupine flour

Fig. 6. Bread with egg

Comparing the pictures above, it is concluded that bread with lupine flour is much denser, has less pronounced pores, and also grows worse. When you taste lupine flour bread, an unpleasant aftertaste remains in the mouth, but this bread is moister than bread with egg. In turn, the bread that is with the egg is better grown it has more pronounced and even pores. This bread also has a more pronounced crust. In both breads, the aftertaste of potato starch is no longer felt. However, the bread that is with the egg is not yet the desired result, since the bread seems dry.

To ensure additional hydration of the bread, the addition of hydrocolloids to the bread recipe is tried. In this case, it is psyllium powder. Fig.7 and 8 show the result of the experiment.

Fig. 7. Bread with psyllium in cross section.

As can be seen from Figure 7, the product is palpable, compacted.

Fig. 8. Bread with psyllium from above.

When creating a dough with psyllium, it is very jelly-like, heavy, cracks and holes form in the dough, but when baked, as can be seen in the above pictures, these cracks have smoothed out. Due to the severity of the dough, it is observed that the bread ferments poorly. The crust is thin, breaking. When cutting bread, the jelly-like structure has been preserved, the author concludes that psyllium does not give the desired result.

One of the last experiments is devoted to making bread wetter, more elastic and improving nutritional value. Applying the knowledge gained during the studies, considering the analysed literary sources, the author decides to add fatty substances and additional proteins and other hydrocolloids to the recipe.

Vegetable fats are put forward as a raw material, which would be a source of fatty substances, more precisely, olive oil. To increase the proportion of protein in the product, bean flour is put forward as a potential raw material. To improve the general acceptability and elasticity of the product, xanthan gum is added. The raw materials of the final product are water, rice flour, bean flour, potato starch, tapioca starch, egg, olive oil, rice flour starter, baking powder, xanthan gum, salt.

4. Conclusions

- Gluten is an important binder in bread, which is missing in alternative flour bread, it is impossible to replace it with 1 ingredient, therefore, to replace it, it is necessary to use a combination of several components, basically: hydrocolloids, starches, proteins.
- Experimentally determined raw materials of alternative flour bread: water, rice flour, bean flour, tapioca starch, potato starch, egg, olive oil, rice starter, baking powder, xanthan gum, salt.
- Alternative flour bread dough has a liquid consistency compared to a bread dough that contains gluten.
- Psyllium fibre is most common hydrocolloid used in gluten-free bread production, it adds moisture to the gluten-free bread dough.

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