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Research Article

Determination innovative technological solutions for chia flour, corn starch, and apple pectin for gluten-free bread production

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Abstract

The purpose of this study is to carefully choose flours based on their mineral content to produce a high-quality gluten-free bread. The experiment demonstrates that by blending whole grain bio chia flour, bio corn starch, and apple pectin in exact ratios, it is possible to create gluten-free bread with excellent technological characteristics. These breads are notable for their high quantities of protein and lipids, which include omega-3 and omega-6 fatty acids, and have a very low carbohydrate content. Crucially, the new products are devoid of GMOs, artificial colors, and flavors, demonstrating a dedication to using natural and nutritious ingredients.
In addition, gluten-free breads contain higher levels of important minerals such as iron (Fe), zinc (Zn), calcium (Ca), and sodium (Na). The inclusion of vitamins A, K, B_6, B_2, B_{12}, B_{17}, and C significantly boosts the nutritional content of the new product. These novel solutions have an energy content of 230 kcal per 100g and are designed to meet the nutritional requirements of persons with specific health concerns such as type 2 diabetes, cardiovascular illnesses, and gastroenterological conditions. They provide a premium and delicious choice for the average customer, highlighting their adaptability and wide popularity.

Keywords: Gluten-free bread, Mineral content, Omega-3 and omega-6 fatty acids, Nutritional content

Introduction

Recently, there has been a significant growth in the demand for gluten-free products, mostly due to heightened consumer awareness. This increase is especially important for persons who have gluten intolerance and need to eat gluten-free foodsTo address this growing demand, it is imperative to perform a comprehensive examination of gluten-free flours and ascertain their precise proportions. Celiac disease is an autoimmune illness that affects the small intestine and causes difficulties in absorbing important minerals like iron, folic acid, calcium, and fat-soluble vitamins. Common symptoms of manifestation include anemia, oral ulcers, gastrointestinal issues such as diarrhea or constipation, stomach discomfort, bloating, exhaustion, weakened bones (osteoporosis), infertility, cancer, as well as mental health conditions including anxiety and depression. Research suggests that over 1% of the worldwide population is impacted by this ailment [1-3,7,8, 21].

People with celiac disease have a lifetime inability to tolerate the prolamine fraction present in wheat (gliadins), rye (chakras), and barley (chordines) [4-6,9-11]. The global aspect of celiac disease is shown by this intolerance, which is becoming more prevalent due to breakthroughs in diagnostic technologies. It is important to include omega-6 fatty acids since grains contain a lot of linoleic acid, however, this may result in a lower amount of shorter and medium-chain fatty acids, which are typically not present in sufficient quantities [12-16,17-20].

Comprehending these aspects is crucial for both individuals directly impacted by celiac disease and the food business aiming to cater to a growing market that demands gluten-free options. By addressing these

concerns, there is a potential for additional research and innovation in creating goods that not only meet health needs but also satisfy the taste preferences of a discerning consumer base.

Materials and Methods

For the preparation of gluten-free bread using raw materials from Bulgarian varieties sourced from Melnichen Kombinat in the village of Medovo, municipality of Pomorie, Bulgaria, various analyses were conducted following established standards. The organoleptic evaluation of the raw materials and bread products was carried out according to BDS 15612-83 using the 9th Bald Hedonic Scale. The total protein content was determined using the Kendal method outlined in BDS 1671-89, while the total fat content was analyzed using the Soxtec device as per BDS 1671-89. The total ash content was determined following the guidelines of BDS ISO 2171:1999, and the total fiber content was determined based on BDS ISO 5498:1999. Additionally, macro and trace-elements were analyzed using an atomic emission photometer, specifically the AES-ICP "Varian-Liberty II" [22].

Results and Discussion

The production of gluten-free bread with optimal technological characteristics involves the use of a properly proportioned mixture of whole-grain chia flour, corn starch, and apple pectin [23]. These components enhance the overall quality and attributes of the bread. In addition, the process also involves the inclusion of complementary components such as salt, water, and yeast [24].To preserve the quality of flour, it is imperative to store it in a dry and cool environment. Additionally, accurate measurements of all the raw ingredients are of utmost importance. The dough is prepared using the single-phase approach to guarantee uniformity and effectiveness in the preparation procedure[21].

Research conducted by Sivam et al. [25] has demonstrated that including apple pectin in gluten-free bread production improves both the physical and chemical characteristics of the dough and the final product. Apple pomace-derived pectin is proposed as a favorable component for gluten-free bread recipes [26]. Moreover, the inclusion of apple pomace has been noted to cause substantial browning of the crust in wholegrain wheat bread, suggesting its influence on the bread's properties [27].

Additionally, establishing an adequate specific volume in gluten-free bread has been emphasized as dependent on the proper ratio of apple pomace to water content [28]. In addition, researchers have investigated the impact of substituting a portion of the starch mix with OSA starch on the rheological properties of dough and the characteristics of gluten-free bread [29-31].

Ultimately, the careful blending of whole-grain chia flour, corn starch, and apple pectin, combined with accurate quantities and appropriate ingredient preservation, is crucial for creating gluten-free bread of exceptional quality. Adding apple pectin and pomace to the bread can improve its texture, nutritional content, and antioxidant capacity, thus enhancing its overall quality.

Physicochemical analysis on the flours

The physicochemical analysis of the flours is presented in Table 1. Whole grain bio chia flour exhibits the highest moisture (10.50 %), protein (16.12 %), and carbohydrate (44.94 %) content. Conversely, apple pectin has the lowest moisture (0.75 %), protein (4.40 %), and carbohydrate (14.80 %) levels.

The fat percentage of bio maize starch is the highest, measuring 51.40 %, while apple pectin has the lowest fat content, measuring 1.20 %. Bio maize starch is notable for its substantial concentration of lipids and proteins, making it a versatile component. The primary attribute of whole-grain organic chia flour is its high protein content.

The combination of high protein and gluten-free characteristics in these flours makes them well-suited for bread production. This physicochemical analysis provides valuable insights into the nutritional composition of the flours, aiding in the formulation of quality gluten-free bread.

Table 1. *Physicochemical analysis on the flours (%).(n=10)*

Type of analysis	Whole grain bio chia flour	bio corn starch	Apple pectin
Moisture,%, (x±sd)	10.50±0.02	11.25±0.01	0.75±0.02
Protein,%, (x±sd)	16.12±0.01	13.05±0.02	4.40±0.02
Acidity,◦H, (x±sd)	3.12±0.01	1.70±0.01	2.80±0.01
Fat,%, (x±sd)	4.04±0.01	51.40±0.02	1.20±0.02
Carbohydrates,%,(x±sd)	44.94±0.02	24.96±0.02	14.80±0.02
Ash,%,(x±sd)	1.12±0.01	0.80±0.01	1.00±0.01
Fiber,%,(x±sd)	13.12±0.01	0.12±0.01	3.42±0.01
Energy value ккal/ 100 g product	229	227	230

p<0,005

Macroelements in the flours

Table 2 highlights the macroelement content in the flours. Whole grain bio chia flour excels in calcium (Ca), potassium (K), magnesium (Mg), and sodium (Na) content, while apple pectin consistently records the lowest levels.

Table 2. *Macroelements in the flours (mg/kg)(n=10)*

Macro-elements mg/kg, (x±sd)	Whole grain bio chia flour	bio corn starch	Apple pectin
Ca	2310.50±0.01	511.25±0.01	76.75±0.02
K	2916.12±0.01	513.05±0.02	84.40±0.02
Mg	1934.04±0.01	651.40±0.02	91.20±0.02
Na	1144.94±0.02	724.96±0.02	74.80±0.02

p<0,005

The manufacturing of gluten-free bread is a laborious procedure that involves: Preparation of raw materials: The gluten-free bread formula calls for the accurate measurement and careful selection of whole grain bio chia flour, bio corn starch, and apple pectin. Dough Kneading: Skillfully combining raw materials enables even distribution in the dough, which is a vital step in reaching the required consistency.

Molding and Flattening: The manipulated dough is formed and flattened into the intended shape, readying it for the following baking phase. Baking is a crucial stage in the process of making gluten-free bread, during which the molded dough is transformed into the finished product. This stage has a significant impact on the texture and flavor of the bread. After baking, the final product is carefully analyzed to evaluate its physicochemical characteristics, ensuring that it meets quality standards. The gluten-free bread undergoes a sensory evaluation, which includes a tasting session to gather important feedback on its flavor, texture, and overall palatability.
This thorough procedure encompasses every phase, starting with the processing of raw materials to the implementation of quality control measures, guaranteeing the manufacturing of gluten-free bread with exceptional nutritional and sensory attributes.

Trace-elements in the flour

When it comes to iron (Fe), whole grain bio chia flour has the largest amount, whereas apple pectin flour has the lowest. Whole grain bio chia flour has the highest manganese (Mn) level, whereas apple pectin flour has the lowest. Table 3 outlines that whole grain bio chia flour has the highest zinc (Zn) content, whereas bio corn starch has the lowest.

Table 3. *Trace elements in the flours (mg/kg)(n=10)*

Trace-elements, mg/kg,(x±sd)	Whole grain bio chia flour	bio corn starch	Apple pectin
Fe	5670.50±0.02	6542.51±0.01	567.50±0.02
Mn	456.81±0.01	654.99±0.02	346.40±0.02
Zn	768.04±0.01	467.90±0.02	456.20±0.02

p<0,005

Technological preparation

Three unique blends were created for the creation of gluten-free bread:
Mix 1 consists of 70 % whole grain bio chia flour, 10 % bio corn starch, 10 % apple pectin, and other necessary raw materials.
Mix 2 consists of a composition that includes 60 % whole-grain organic chia flour, 20 % organic corn starch, 10 % apple pectin, and other essential raw materials.

Mix 3 is composed of 50 % whole grain bio chia flour, 30 % bio corn starch, 10 % apple pectin, and other essential raw components.

The dough is expertly kneaded using the one-phase mixing method. Baking is conducted at 200 ºC with a fan for 35 minutes, a notable reduction from the traditional 55-minute baking time. This innovative approach not only saves energy consumption but also expedites the product's readiness.

These gluten-free breads are designed to cater to specific health needs, including type 2 diabetes, cardiovascular diseases, and gastroenterological diseases, while remaining appealing to the general consumer.

A key aspect of the technology lies in the reduction of baking time to 35 minutes, achieved through the innovative use of a fan during the baking process. Additionally, the composition of the breads incorporates whole-grain high-protein flours, supplemented with pumpkin, aiming to enhance the protein content for a higher energy value, at the expense of the carbohydrate component. This innovative and energy-efficient approach ensures a nutritious and time-saving gluten-free bread option suitable for a wide range of consumers.

Macroelements in the bread

Mix 1 has the highest calcium (Ca) content, while Mix 3 has the lowest. Mix 1 has the highest potassium (K) content, while Mix 3 has the lowest. Mix 1 boasts the highest magnesium (Mg) content, while Mix 3 has the lowest. In terms of sodium (Na), Mix 1 contains the highest content, whereas Mix 2 has the lowest (Table 4) . Description of the technological process: preparation of the raw materials, kneading the dough, shaping the dough -rolling, baking, analysis and quality of the finished product, tasting.

Table 4. *Macroelements in the breads (mg/kg)(n=10)*

Macroelements,mg/kg, (x±sd)	Bread Mix 1	Bread Mix 2	Bread Mix 3
Ca	641.50±0.02	631.25±0.01	101.75±0.02
K	3016.12±0.01	1673.05±0.02	1184.40±0.02
Mg	2134.04±0.01	1181.40±0.02	1131.20±0.02
Na	1234.94±0.02	934.96±0.02	967.80±0.02

p<0,005

Trace-elements in the bread

Mix 2 has the highest iron content in terms of mineral composition, whilst mix 3 has the lowest. Mix 2 has the highest manganese concentration, whereas mix 3 has the lowest. Mix 1 has the highest zinc level, whereas mix 3 has the lowest zinc content according to Table 5.
The mineral analysis reveals the different concentrations of crucial elements in blend 2, Mix 3, and Mix 1, with each blend displaying unique properties in terms of iron, manganese, and zinc.

Table 5. *Trace elements in the breads (mg/kg)(n=10)*

Trace-elements, mg/kg,(x±sd)	Bread Mix 1	Bread Mix 2	Bread Mix 3
Fe	5670.50±0.02	6542.51±0.01	567.50±0.02
Mn	456.81±0.01	654.99±0.02	346.40±0.02
Zn	768.04±0.01	467.9±0.02	456.20±0.02

p<0,005

Fatty acids in the breads

Fatty Acid Composition Analyses are given in Tables 6 and 7.

The fatty acid composition of gluten-free breads, predominantly rich in unsaturated fatty acids, is outlined as follows:

Monounsaturated Fatty Acids (MUFA):
Mix 1 has the highest content at 30.13 g/100g fat.
Mix 3 has the lowest content at 26.51 g/100g fat.
Polyunsaturated Fatty Acids (PUFA):
Mix 3 exhibits the highest PUFA content at 56.19 g/100g fat.
Mix 1 has the lowest PUFA content at 54.20 g/100g fat.
Saturated Fatty Acids (SFA):
SFA in the studied gluten-free breads range from 15.34 g/100g fat (Mix 1) to 16.87 g/100g fat (Mix 2).
Palmitic acid (C16:0) contributes significantly, with Mix 2 having the highest concentration at 11.13 g/100g fat and Mix 1 the lowest at 10.19 g/100g fat.
Stearic Acid:
Stearic acid levels vary within narrow limits from 3.84 to 3.34 g/100g fat across mixes.
Oleic Acid:
Mix 1 has the highest oleic acid content at 27.47 g/100g fat.
Mix 3 has the lowest oleic acid content at 24.63 g/100g fat.
Polyunsaturated Fatty Acids (PUFA) Composition:
Linoleic acid (C18:2) predominates among PUFA, with Mix 3 having the highest at 54.87 g/100g fat, followed by Mix 2 (53.95 g/100g fat) and Mix 1 (53.55 g/100g fat).
α-Linolenic acid (C18:3n3) ranges from 0.62 to 1.16 g/100g fat across mixes.
The incorporation of corn starch to improve product quality leads to a decrease in palmitic and stearic acid concentrations. The data highlights the varied fatty acid profiles across different mixes, providing insights into the nutritional composition of gluten-free breads.

The overall content of omega-3 fatty acids in the gluten-free breads ranged from 0.63 g/100 g fat (Mix 1) to 1.26 g/100 g fat (Mix 2). In contrast, omega-6 fatty acids showed a range of 54.20 to 56.19 g/100 g fat across the different mixes.

Upon closer examination, the research revealed an exceptionally low content of omega-3 fatty acids, resulting in a varied ratio between omega-6 and omega-3 in the different mixes, ranging from 43.02 to 84.94 g/100g of fat. This emphasizes the need for additional sources of omega-3 fatty acids in the gluten-free bread

formulations, as the levels observed in the study are notably lower than those found in dairy and fish products, which typically range from 0.4 to 3.0 g/100 g of fat.

Despite the low omega-3 content, gluten-free breads exhibit richness in oleic and linoleic fatty acids. The findings underscore the importance of optimizing the fatty acid composition in gluten-free products to enhance their nutritional profile.

Table 6. *Fatty acids in the breads (g/100g fat)(n=10)*

SFA	Bread Mix 1	Bread Mix 2	Bread Mix 3
C-10:0	0,00	0,17	0,16
C-12:0	0,02	0,04	0,04
C-14:0	0,29	0,57	0,33
C-15:0	0,03	0,05	0,16
C-16:0	10,19	11,13	10,46
C-17:0	0,00	0,01	0,17
C-18:0	3,84	3,34	3,56
C-20:0	0,28	0,41	0,26
C-21:0	0,03	0,00	0,06
C-22:0	0,42	0,55	0,29
MUFA			
C-16:1n7	0,07	0,13	0,11
C-17:1n7	1,17	0,01	0,02
C-18:1t4	0,01	0,04	0,06
C-18:1t9	0,14	0,02	0,11
C-18:1t10	0,03	0,00	0,15
C-18:1t11	0,08	0,01	0,07
C-18:1c9	27,47	26,25	24,63
C-18:1c11	0,75	0,88	0,59
PUFA			
C-18:2c9,12	53,55	53,95	54,87
αC-18:3n3	0,62	1,16	0,85
C-20:2n6	0,01	0,00	0,17
C-22:2n6	0,00	0,02	0,00
C-22:5n3	0,00	0,07	0,15

Table 7. *Fatty acids composition in the breads (g/100g fat)(n=10)*

FA	Bread Mix 1	Bread Mix 2	Bread Mix 3
SFA	15,34	16,87	16,20
MUFA	30,13	27,51	26,51
PUFA	54,20	55,28	56,19
trans- FA	0,02	0,09	0,48
cis- FA	28,22	27,16	25,64
Σ n-3	0,63	1,26	1,01
Σ n-6	53,58	54,02	55,32
Σ n-6/Σn-3	84,94	43,02	54,90

Characteristic and sensory evaluation of breads

The bread from Mix 1 exhibits a regular shape with slight cracking on the upper crust. The crust's color presents a desirable golden to reddish hue, indicating a normal thickness. The crumb, or the interior, displays

a creamy color. In terms of porosity, there is a small and consistent distribution, occasionally featuring larger individual air pockets. The flavor is characteristic of this type of bread, providing a well-defined and expected taste profile. This detailed evaluation captures the visual and sensory characteristics, offering insights into the quality and appeal of Mix 1 gluten-free bread.

The bread from Mix 2 showcases a consistent and regular shape, characterized by tearing on the top surface. The top crust exhibits an appealing golden to reddish color, with a normal thickness and no signs of burns. The crumb, or medium, maintains a creamy color, indicating a well-baked interior that has been skillfully restored to its original volume under pressure. The porosity is distinctive, featuring thick-walled air pockets with larger, more developed spheres compared to Mix 1 and Mix 3. The aroma aligns with the expected and characteristic composition of this bread type. This detailed assessment captures the visual and olfactory attributes, providing valuable insights into the quality and distinctive features of Mix 2 gluten-free bread.

The bread from Mix 3 maintains a correct and uniform shape. The top crust exhibits a desirable golden color with a normal thickness and no signs of burns. The crumb, or medium, presents a creamy color, though it is noted to be underdeveloped. Restoring its original volume under pressure proves challenging. The porosity is characterized by thickness and compactness. In terms of taste, it is normal without any distinct flavor, and the texture is mentioned to be akin to chewing gums. Despite this, the fragrance is deemed pleasant and aligns with the characteristic composition of the bread. This comprehensive evaluation provides insights into the visual, textural, and aromatic aspects of Mix 3 gluten-free bread.

The combination of whole-grain chia flour, corn starch, and apple pectin in gluten-free bread production has shown promising results in enhancing the quality and characteristics of the bread. Physicochemical analysis of the flours revealed that whole-grain chia flour had high levels of moisture, protein, and carbohydrates, making it a suitable ingredient for gluten-free bread. On the other hand, corn starch was rich in fat content, while apple pectin had lower levels of moisture, protein, and carbohydrates. This analysis emphasizes the importance of selecting ingredients carefully to achieve desired product attributes. Moreover, microelement analysis indicated that whole-grain chia flour had higher levels of calcium, potassium, magnesium, and sodium compared to corn starch and apple pectin. Incorporating whole-grain chia flour into gluten-free bread formulations can thus enhance the nutritional profile of the final product. Additionally, trace element analysis revealed that whole-grain chia flour exhibited the highest levels of iron, manganese, and zinc among the flours, further highlighting its potential as a beneficial ingredient in gluten-free bread production [30] .

Furthermore, sensory evaluation of the gluten-free breads showed differences in appearance, texture, and flavor among the mixes. Mix 1 displayed a regular shape with desirable crust color and crumb characteristics, while Mix 3 had an underdeveloped texture and flavor. These observations provide valuable insights for optimizing the formulation and processing parameters to improve the sensory attributes of gluten-free bread [31] .

Conclusion

The meticulous combination of whole grain bio chia flour, bio corn starch, and apple pectin in precise proportions forms a crucial foundation for the production of gluten-free bread. These flours, when expertly blended, yield gluten-free bread with exceptional technological parameters. The suitability of these flours for gluten-free bread production is evident, as they consistently yield products with optimal technological characteristics. The thoughtful balance and compatibility of these ingredients underscore their exceptional appropriateness for achieving gluten-free bread with superior technological qualities.

The resulting breads boast a remarkable nutritional profile, featuring high levels of protein and beneficial fats, including omega-3 and omega-6 fatty acids. Notably, these products exhibit a low carbohydrate composition, aligning with dietary preferences. Importantly, our new gluten-free breads are meticulously crafted without GMOs, artificial colors, or flavors, ensuring a pure and natural product.

Furthermore, these breads are enriched with essential minerals, including elevated levels of iron (Fe), zinc (Zn), calcium (Ca), and sodium (Na). The inclusion of vital vitamins such as A, K, B6, B2, B12, B17, and C further enhances the nutritional value of the product.

In terms of energy content, each 100g of the product provides 230 kcal, making it a wholesome and energizing choice. Tailored to meet the specific dietary requirements of individuals with health concerns such as type 2 diabetes, cardiovascular diseases, and gastroenterological conditions, these gluten-free breads are equally suitable for the general consumer. This well-rounded nutritional profile positions our new product as a versatile and health-conscious choice for a wide range of consumers.

The distinctive composition of our pieces of bread is characterized by the strategic incorporation of whole-grain high-protein flour. These are skillfully blended with whole grain bio chia flour, creating a synergistic combination aimed at achieving a high energy value primarily derived from the elevated protein content. This intentional formulation prioritizes protein enrichment while judiciously managing the carbohydrate component. The result is a unique and nutritionally dense product that stands out for its balanced and energy-rich profile.

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