Akaki Tsereteli State University
Faculty of Engineering and Technology

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Development of gluten free floury product technologies with high biological value

Presented for awarding an academic doctoral degree in food technology
(0104)

Thesis Herald

Kutaisi, 2018

The dissertation thesis is performed in the Food Technology Department of the faculty of Engineering and Technology of Akaki Tsereteli State University.

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General description of the thesis

Topic actuality

Nutrition is essentially important factor for human defining health, proper development and working capacity. So organizing of nutrition based on scientific-hygienic bases for population is considered to be the common state objective.

The formula of nutritional products of XXI century implies including and constant use of functional substances having predefined properties, inreached with essential nutritional substances, microelements and biologically active substances in food ration additionlly to tradicional products.

Processing of food products of functional purpose, aimed at prophylaxis and complex treatment of alimentary dependent diseases is one of the actual issues in the field of healthy nutrition. Such diseases include celiac, during which using of food products prepared on the base of wheat, rye, barley, some pseudocereal and legumes containing gluten, causes a wide range of pathological changes in the body.

Nowadays, the problem of celiac (glutenal enteropathy) is more relevant all over the world. Celiac is a congenital genetic disease in which gluten intolerance is maintained throughout life. Many people suffer from gluten containing food allergy. The principle difference between these diseases is that gluten allergies are temporary and it diseppares with age by keeping adequate diet, but celiac is never lost. According to the latest data from global health and gastroenterological organizations, the number of people with celiac disease is 2% of the world's population and is increasingly characterized by a growing tendency. In Georgia, where the cultures of wheat flour, cereal confectionery and culinary products, this disease is associated with a particular risk factor. In recent years, the celiac has become the most common disease of the small intestine because of food quality and severe deterioration of ecological conditions.

Nowadays Dorokhovich V.V, Sabelnikova E.A, Shnaider D.V, Revnova M.O, Averina, Janatuinen E. K., Logan R. F., Mitt K., Collin P. and other leading scientists work on the problems of organization of dietary nutrition for the population with gluten-sensitive celiac desease. Their thesises contributed to the development of the theoretical and practical aspects of celiac treatment and prevention.

The main disadvantage of the product, prepared on the base of gluten free raw materials, is its low nutritional value. They are characterized by short term storage, rapid fasting, unequal porosity, insufficiently developed structure, and mostly important is organoleptic properties.

In order to optimize the ration of people with celiac disease, it is important to

enrich the product with essential nutrients. For this purpose, the use of local resources, including non-conventional ingredients, the correct selection of which ensures the normal function of the digestive system and general metabolism in the body of people with celiac disease.

Taking into consideration all the above, conducting research directed to the processing of innovative technologies of production of gluten free bakery products is actual.

Main goals and objectives of research:

The Goal of the dissertation thesis is to develop innovative technological processes for the production of gluten free bakery products based on complex research of enzymatic semi-finished items.

Objectives of the research. According to the above mentioned goal it was necessary to fulfil the following objectives:

- Systematization and analysis of scientific and technical literature and patent information of patriotic and foreign research topics;
- Selection of local aggregate vegetable raw materials and study their physico-chemical, biochemical and techno-functional properties;
- Research of germination process of the selected gluten free cereal and leguminous crop;
- Optimization of germination process of the raw material by using mineral waters of Georgia;
- Research of dynamics of changes of biologically active substances, germinating speed and energy in cereal under the influence of mineral waters;
- Development of the technology of enzymatic semi-finished product;
- Research of microbiological, technological, microstructural and reologic properties under the influence of various technological factors;
- Enrichment of gluten free bakery products with biologically active ingredients and their impact on product quality;
- Processing of the technology of gluten free bakery production having functional purpose using enzymatic semi-finished product;
- Determining of the caloricity, nutritional value, microbiological safety of the obtained products. Research of the quality of ready products during the storage process;
- Industrial approbation of the processed technology;
- Creating of projects of technical documentation.

Scientific innovation of the thesis.

Based on the analysis of literary sources and patent materials, using of

traditional gluten free raw materials - Georgian soya, lentils, amaranth, topinambur, various functional supplements - food fibers, flour of germinated cereal and thickeners scientifically substantiated in the production of gluten free bread.

The chemical and micronutrient composition, physico-chemical, biochemical, techno-functional properties of the local gluten free raw materials – cereal and leguminous crops have been studied.

High bioavailability ingredients are selected and approbated for modified enzymatic semi-finished products, providing optimization of alcohol and acidic fermentation, diversity of fermentation products, increasing nutritional value of products, formation of texture, prolonging the storage time, providing microbiological safety, forming taste and aromatic properties.

Waters of various mineralizations, including weak radon chloride-hydrocarbonate-sulfate mineral water, have been used primarily for optimizing the process of germination. This has resulted in a significant increase in the amount of antioxidant capacity and micronutrients and high functional properties.

By innovative approaches, the technology of new generation, gluten free bakery products have been developed providing activation of the body's protective and recovering functions in general.

The innovation of the developed technology is approved by the patent of Georgia P 6562 "The method of preparation of gluten free bread with high biological value for patients with celiac disease (Date of Issue: 2016-11-04).

Practical importance of the work:

By composite using of local agglutenic raw materials and fermented semi-finished products, new recipes and technologies of bakery products are processed for patients with celiac disease which provide high consuming properties and biological value of the product.

Industrial approbation was carried out in experimental shop of the Food Technologies Department of Akaki Tsereteli State University and in multi-profile enterprise "ALAT". A new assortment of gluten free bread has been prepared, which is recommended for people suffering from celiac and protein gluten intolerance.

Based on the results of the research technical documentation has been worked out - projects of recipes of gluten free bread.

Scientific provisions for the presentation:

- Results of research of local gluten free raw materials, biochemical and technological properties;
- The results of experiments carried out for increasing bioavailability of gluten

free raw products;

- Results of the experiments of influence of Georgian mineral waters on optimization of germination process of cereals and leguminous crops;
- Materials for processing of recipes and technological parameters of gluten free bakery products.

Work approbation

Results of Dissertation research were periodically reviewed at the Student and Young Scientists Republican and International Conferences, at the sessions of Food Technologies Department of Engineering-Technological Faculty of Akaki Tsereteli State University (2014-2017).

Thesis results are discussed and published in following materials of international scientific and practical conferences:

1. International Scientific and Practical Conference "Science and Innovative Technologies". Kutaisi, Atsu, 28-29 November, 2014.
2. International Scientific - Practical Conference "Innovative Technologies for Functional Destination Food Production". Kutaisi, Atsu, April, 2015.
3. International "Scientific-Practical Conference" Modern Engineering Technologies and Environmental Protection". Kutaisi, Atsu, 19-20 May, 2016.
4. International Scientific-Practical Conference "Achievements and Development Prospects of Bread and Confectionery Industry". Kiev, National University of Food Technologies, September, 2015.
5. International Scientific-Practical Conference "Achievements and Prospects of Bread and Confectionery Industry". Kiev, National University of Food Technology, September, 2017.

Publications:

According to the results of the research, 9 scientific papers, including 4 articles in International Reference Magazines, have been published; patent for the invention P 6562 (published in the Patent Bulletin N20, 2016, p.10) is accepted.

Structure and Volume of the thesis

Dissertation thesis is represented by 154 pages printed on computer and contains 4 chapters, main conclusions and 168 literature sources, 27 timetables, 13 pictures and 21 draughts.

General contents of the thesis

Dissertation thesis contains introduction, 4 chapters, main conclusions and used references.

Introduction is about topic actuality, goals and objectives, scientific innovation and practical value.

First chapter – Literature review – the medical aspects of celiac disease are

discussed; modern methods of combating gluten enteropathy are analyzed. It is shown that the main medication of celiac disease is gluten free diet, which implies total exclusion of protein - gluten from food products; the contemporary condition and perspectives of the production of gluten free food are discussed; worldwide manufacturers of low-protein containing and gluten free products and consumer market of medicinal and prophylactic products of Georgia are characterized; the role of germinated grain in modern nutrition is discussed, technological processes of food production using germinated grain, changing of the main components of the grain in the process of germination is analyzed.

The second chapter - discusses research objects and methods.

The object of research was cereal and leguminous cultures from various regions of Georgia: soy, lentils, peas, amaranth and topinambur, collected in 2015-2017. The study also included corn starch, apple and citrus pectin, apple and citrus extraction flour, table salt, vegetable oils, pressed yeast, drinking water that comply with all requirements of valid normative documents and are permitted in the production of gluten free products. As semi-finished products we used fermented semi-products, yeast and dough. The main object of the research was gluten free bread prepared from the listed raw materials and functional ingredients.

During determination of the main quality indices of raw materials, semi-finished products and ready-made products, we used common standard methods as well as special techniques and tools used during techno-chemical control of baking.

Determining of proteins was performed by Kjeldahl method Determination of fats – by Soxhlet method; determining of reducing sugars - by micro-method of K. N. Chizhova and A. N. Sonkina; determining of ascorbic acid – by GOST 24556-89; Content of thiamine and ribonflabin was determined by fluorometric method; air producing and air capture capacity, of semi-finished product, dough raising were determined by rheofermentometer; the amount of aromatic substances in the bread was measured by R. Tokareva's and V.L. Cropovitch's method; organoleptic evaluation of the product quality was determined by a profiled method; determining of gluten content - by immunoferment method.

Chapter 3. Selecting and analyzing of gluten free raw products.

At the first stage of the research we have selected the following gluten free raw materials: soy, lentils, peas, amaranth, topinambur, selected from abundant Georgian bioresourses. They were selected by the following principles: 1) All of the above listed raw products are gluten free and low-glycemic (their glycemic index is less than 40); 2) Selected raw products are characterized by high content of vegetable (dietary) proteins; 3) The raw products are distinguished by the high

content of biologically active substances, and they are grown on farms of Western Georgia.

The chemical composition of the selected raw products (the total amount of proteins, fats, carbohydrates, food fibers, as well as ashes and water content), biochemical and technological properties have been studied. Based on the obtained results, nutritional and energy values are calculated. Results of the research are presented on Figure 1.

Content of macro, microelements and vitamins in the selected raw materials has been studied (Table 1).

Amaranth leads according to the amount of vitamins. The content of calcium and potassium is the highest in soybean and the amounts of phosphorus and magnesium also high in amaranth and soybean. As for the microelements, the green peasis especially noticeable. Lentil leads with iron content.

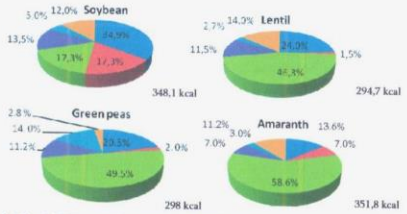


Fig. 1. Chemical composition, nutritional and energetic value of raw product

Among technological features, we studied the ability of water absorbtion by raw products. The wheat grain was taken as control. The results of the experiment are presented in Fig. 2.

It has been established that soybean and peas have the most effective water absorption ability. The maximum duration of germination was about 9 hours for soybean, peas, green lentil, and the peak of germination for amaranth was 6 hours. To compare with wheat grains, soya has absorbed 4 times and amaranth is 3,5 times more water.

Table 1.

Content of macro-, microelements and vitamins in selected raw products (mg%)

Components	Crop		Legumes			Root crop
	Wheat	Amaranth	Soybean	Lentil	Peas	Topinambour
Vitamins						
β – carotene	0,01	0,01	0,07	0,03	0,01	0,012
B1	0,44	0,37	0,94	0,50	0,81	0,07
B2	0,15	0,38	0,22	0,21	0,15	0,06
B5	1,10	1,86	1,75	-	2,2	-
B6	0,50	0,69	0,85	-	0,27	-
B9 ,mcg	37,5	82	200	-	16	-
Vitamin C	-	4,2	-	-		6,0
Vitamin E	3,0	1,19	1,9	0,5	0,7	0,2
PP	7,3	0,92	9,7	5,5	6,5	1,3
Choline, mcg	90	69,80	270	-	200	-
Macroelements						
Calcium	54	159	348	83	115	20
Magnesium	108	248	226	80	107	12
Sodium	8	4	6	55	33	3
Potassium	337	508	1607	672	873	200
Phosphorus	370	657	603	390	329	78
Microelements						
Iron	5,4	7,61	9,7	11,8	6,8	0,4
Zinc	2,8	2,9	2,0	2,4	3,18	-
Copper, mcg	470	525	500	660	750	-
Manganese	3,8	3,3	2,8	1,2	1,75	-
Selenium, mcg	29	-	-	19,6	13,1	-

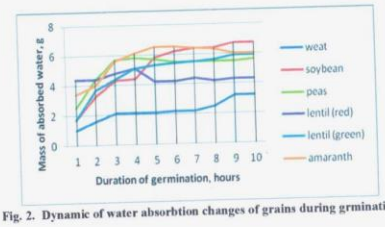
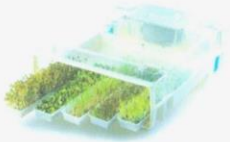


Fig. 2. Dynamic of water absorbtion changes of grains during grmination

To enhance the biological value of the selected raw materials, we have used perspective and safe method of activation of its own endo- enzymatic system (enzyme modification), occurring during germination in wet area.

At the initial stage, we selected cereals by removing of foreign impurities, damaged and "dead" grains. After that several times we werehed and disinfected them with a weak solution of potassium permanganate. Then again wash them with clean water and only after that soaked them. We've been doing it for 12 hours. The duration of soaking for each grain was individual and consisted of: 8 hours for wheat, 7 hours for soy bean, peas 3 hours, green lentil grains absorbs water for 8 hours, the soaking duration for amaranth is 6 hours.

After soaking, we planted grains in an automated sprout (Fig.1).



Pic 1. Automated sprauter

We germinated grains untill 2-5mm long sprouts were produsedand only after that we took samples for chemical analysis. We have determined the following parameters - water, proteins, fats, carbohydrates, food fibers and the total number of ashes.

Chemical composition of germinated grains, nutritional and energy value is given in Fig. 3.

The energy value decreased significantly after the germination of grains. Soybean caloricity decreased by 61% (212,2 kcal). The energy value of the peas decreased by 125.3 kcal , 42%. As for the green lentil, caloricity, during germination, is reduced by 56% or 164.9 kcal. A great amount of energy is spent by amaranth. Its caloric loss is 48% or 169.8 kilocalories.

The amount of vitamins, macro and microelements was determined to assess the biological value.

According to the recommendations in the literature, the length of the sprouts should not exceed 2 ÷ 5 mm.

The dynamics of changes in the length of sprouts within 5 days is reflected on Fig. 4. Monitoring was conducted every 12 hours.

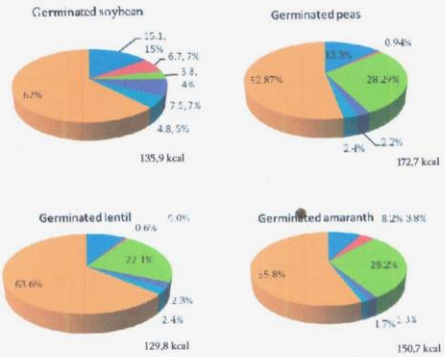


Fig 3. Chemical composition, nutritional and energetic value of germinated raw products (in 100g of product)

■ proteins ■ lipids ■ carbohydrates ■ food fibers ■ ashes ■ water

Observations on the changes in the length of the sprouts revealed the optimum timing of germination: 48 ÷ 60 hours for wheat, 60 ÷ 72 hours for soy; The optimal period of lentil is 60-72 hours; the sprout of the pea grain reached 2 mm in 60-72 hours, as for the amaranth, duration of germination is 120 hours.

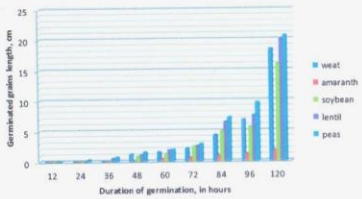


Fig. 4. Dynamics of changes in length of crop and legumes germinated grains in the 120 hours (5 days) germinating process.

It is established that during germination, changes of main components of each raw material reflected in the energy value. We can see that the reduction of proteins, fats and carbohydrates has resulted in a significant decline in calories of sprouts (Table 2).

Table. 2.

The analysis of caloricity in germinated grains

Indices	soybean		peas		lentil		Amaranth	
	Dry	Germinated	Dry	Germinated	Dry	Germinated	Dry	Germinated
Caloricity,kkal	348,1	135,9	298	172,7	294,7	129,8	351,8	182
From proteins	156,4	60,4	82	52,2	96	36	54,4	32,8
From Carbohydrates	150,5	60,3	198	112,2	185,2	88,4	234,4	116,8
From proyeinz	41,2	15,2	18	8,3	13,5	5,4	63	32,4

Optimization of the germination processes of raw products using mineral waters of Georgia

On the second stage of the research for the purpose of optimization of seed germination process, mineral waters of Georgia were used instead of potable water, these are: mineral water "Borjomi" of average mineralization and mineral water of the Resort Tskaltubo chloride-hydrocarbonate-sulphate containing weak radon, which accelerates the process of germination and reduces by 1,5 – 3,0 hours. Also the process of germination was accelerated and it is reduced by 1,5 – 2,0 days. Best result was obtained by using mineral water of the Resort Tskaltubo containing weak radon. The dynamic of changes of micronutriental composition in researching raw products using Tskaltubo mineral water is reflected on Table 3.

Based on the analysis of the data presented on Table 3, the quantity of macro (calcium, magnesium, sodium, potassium and phosphorus) and microelements significantly increased in sprouts germinated in mineral water to compare with sprouts germinated in potable water, which can be explained by absorption of elements by grains from mineral water and their connection with organic substances, that makes their absorption easier for human.

By the effect of mineral waters, amount of vitamins in the process of germination has significantly increased. Especially should be noted increasing of vitamin C, which was practically not found in the initial raw material, except amaranth were the amount of vitamin C was 4,2 mg%. Dynamics of Vitamin-C change is studied separately as in the process of germination in potable water, using mineral water "Borjomi" and chloride-hydrocarbonate-sulfate mineral water of Tskaltubo containing weak radon. The results are outlined on Fig. 5.

As a result of germination in potable water, content of vitamin C in 48 hours is: in wheat - 4,9 mg%; in amarant - 58,8 mg%; in peas - 32,4 mg%; in soybean - 22.9 mg%; in lentil - 31.6 mg%. By using Borjomi mineral water, vitamin C increased (0,01-0,081%) and the quantity of vitamin C was increased by using mineral water of Tskaltubo containing weak radon (0,03 - 0,146%). Wheat grains were used as controll in all experiments.

At the next stage, we have studied the impact of various factors (temperature, soaking duration, hydromodule - grain and water ratio, watering multiplicity), on the germination process. During germination, we measured the quality of the germination and the energy germination (Fig. 6). The degree of germination is determined by dividing of germinated grains by initial amount (%). The energy of germination is the speed of germination (in %) (within 3 to 15 days).

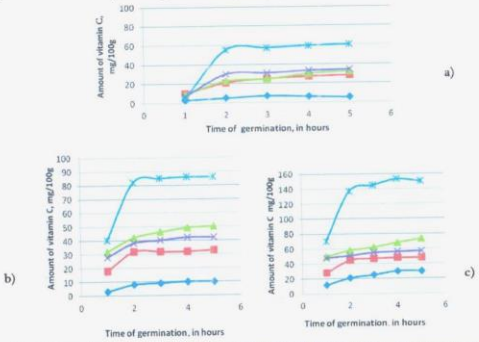


Fig. 5. Dynamic of changes of the amount of vitamin C during the germination process

a) Using potable water; b) Using mineral water „Borjomi"; c) Using Tskaltubo mineral water.

The data shows that the quality of the germination and the energy of germination is observed in all samples using mineral water. Especially increasing of parameters must be noted in green peas. The quality of germination of peas using potable water is- 90%; while using mineral water - 96%; Also, the energy of germination has been changed and and has increased from 95% to 98%.

The optimal parameters of the process have been determined as a result of the experiments: temperature 25 ÷ 30^{0}C, the further increase up to 40^{0}C did not affect on the process of germination; optimum hydromodule is 1 portion of grains per 2 ÷ 2,5 portion of water; watering multiplicity is 3 - 4 times a day; the duration of soaking is 6 hours (with several rinsing).

Fig. 6. Degree of germination and energy of germination of grains

I – Degree of germination using potable water;
II – Energy of germination using potable water
III - Degree of germination using mineral water;
IV - Energy of germination using mineral water.

Chapter 4. Developing the technology of gluten free bread.

4.1. Selection of structural agents and study of their impact on rheological properties of dough, physico-chemical and organoleptic indicators of the bread quality

The production of gluten free bread from agglutenic raw products is not possible without structural agents. So in the initial stages of the research we studied the possibility of using modern structural agents in agglutenic flour composition, such as food fibers and pectin - products of citrus processing. For formation of the trial composition, as control we used the bread flour mixture of "rice" with soybean protein isolator (TY 9295-288-11163857-2014), which consists of extruded starch, rice flour, soybean protein isolator, salt and sugar.

For the purpose of selecting and submitting of structural agents in flavored mixture, we studied the effect of flavored composition on the quality of the gluten free bread. Instead of extruded starch in composition, which has low water absorption capacity, we have used corn starch and citrus fruit processing products - food fibers and pectin with high etherification degree. It has been established that water absorption capacity of citrus fibers and pectin is from 2.2 to 2.7 times higher than the same indices of extruded starch. Therefore, it may be assumed that the replacement of it with citrus food fiber and pectin will improve the structure of the

dough, the physico-chemical (qualitative, compressive) and organoleptic indices of the quality of gluten free bread. It is remarkable that one of the most important indicators of the quality of gluten free bread is the specific volume that indicates the efficacy of the used structural agents.

We have studied the effect of natural citrus fibers and pectin on rheological properties of dough (dynamic viscosity), physico-chemical (acidity, compression) and organoleptic indices of bread quality, for which we prepared dough with 52% humidity, by adding trail composition and mixed structural agents, pressed yeast, vegetable oil and water.

The control sample was made of dough, composed of composite "rice" soy protein isolates and extruded corn starch. The dynamic viscosity of the control dough was 19,26 pa.sec and the bread had the following quality characteristics: the specific volume - 2 cm^3/g, the compressibility - 19 units and the acidity of 0,2 degrees.

Repracement of extruded corn starch with citrus food fibers dosed from 0.3% to 1.5%, led to the increase of the dough viscosity from 6,70 to 16,92 pc and the increase in the special volume of bread from 1,84 to 2,21 cm^3/g. By adding 15% of citrus fibers into the recipe mixture the viscosity approach to the control sample, the volume of bread is higher than the control. Increasing the doses of citrus fibers up to 1,8-2%, sharp increasing of dynamic viscosity is noticed 32,0 pa.sec and worsening of bread quality – special volume of bread was decreased. Gluten free bakery products have low acidity, which negatively affect the tasting properties. Additing of citrus fiber in composition led to the increase of titrated acidity of lactic acid from 0.3 to 0.5 degrees, which led to the formation of a more pronounced taste of ready products.

Increasing the number of citrus food fibers from 0,3% to 1,5% (in ratio with composition mass) has resulted in increasing of bread compressibility compared to the control. The following increase of the amount of fibers led to reducing of the mentioned indicator to 1,8%.

It is determined that the best organoleptic indices were obtained using circus food fibers with the amount from 0,9% to 1,5% which differs from the control sample having more pronounced taste, sharp color of the cortex and the elastic bread crumb. Therefore, we conclude that using of citrus fibers instead of extruded corn starch with 1,2-1.5% amount in the composition of the "rice" with soy protein isolate, is rational.

In the gluten free composition using of citrus pectin 0,5% of the amount, instead of extruded corn starch, the dough was liquid consistency, which led to decreasing of specific volume of ready product. Increasing of the amount of pectin up to 1%, increases the viscosity of the dough, which is positively reflected on the

specific volume and organoleptic characteristics of bread. After the following increase of pectin substantial changes are not caused, so we did not consider it necessary to add more pectin, as the specific volume of bread and organoleptic characteristics were insignificantly shifting. We considered the optimum dose of pectin 1%.

Adding of pectin in floured composition positively reflected on the acidity and compression of ready product. The use of 0.5% pectin has increased bread acidity 3 times to compare with control. On the base of analyzing the organoleptic indices, we can note the positive effect of pectin on all characteristics of bread quality: bread has bulging, brightly colored crust, elastic pale bread crump and pronounced taste.

On the basis of the research we show the possibility of the use of modern structural agents - citrus food fiber and pectin instead of extruded starch in the recipe of gluten free bread and their optimal quantities are determined to improve the consumption properties of gluten free bread.

4.2. Developing technologies of ready semi-finished product and its impact on the quality of dough and ready product.

It is known that gluten free products, due to their high humidity and low acidity, easily undergo spoiling, molding and suffer from potato disease. It is a good substrate for the development of microbes. In order to eradicate these defects, renewable acidic semi- finished products are used to increase microbiological safety. However, the process of preparing semi-finished product is too long, laborious and uncomfortable in the discrete conditions of the production of gluten free bread, it is appropriate to prepare fermented semi-finished product from agglutenic raw materials, using substrates stimulating alcoholic and acidic fermentation.

To prepare the fermented semi-finished product, we used selected and researched local agglutenic raw materials - amaranth and pea flour, flour of germinated soybean, as well as the pressed yeast, together with the traditional raw products. Carbonated mineral water is intended to intensify the fermentation processes, instead of potable water. To stimulate the acidic fermentation, we used soybean fermented milk product made of lacto- and bifidobacteria.

For the processing of the recipe of fermented semi-finished product we were studying the dynamics of acidity accumulation for 8-10 hours in the area with moisture of 65,0%, 28-30^{0}C. It is determined that in the experimental semi-finished product the acidity accumulation was more intensive to compare with the control (Figure 7). The increasing of the acidity must provide more pronounced, harmonious taste and flavor and microbiological stability of ready product.

Experimentally established that the use of fermented semi-finished product results in softening of dough that makes it more effective for further formation.

This gave us the chance to reduce the dough's humidity by 3 to 4% (from 52,0 to 48-49%), also to avoid growing mold and microbiological damage.

Technological parameters of dough preparation for gluten free bakery products are as follows; for control dough: humidity 49%, acidity 1.8 degrees, duration of dough keeping 45 min; the appropriate parameters for experimental dough (using fermented semi-finished product) are following: 49%, 7 degrees, 42 min. Research results have shown that using of fermented semi-finished product provides accumulation of acidity in dough.

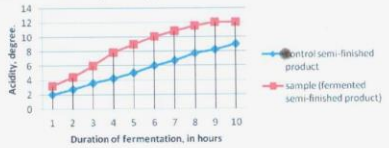


Figure 7. Collection of acidity in fermented semi-finished product during fermentation

We evaluated the ready products by physico-chemical and organoleptic indices. Analysis of the obtained results showed that the acidity of the ready product increased 9,7 times using fermented semi-finished product, compression of bread core - 2,2 times, special volume - by 30% and porosity - by 13.8%. Organoleptic indices were also increased. The obtained sample had a straight form, smooth, sharp crust, porosity thin and equal, taste was characterized with light pleasant acidity. Control samples without fermented semi-finished product were characterized by unleavened taste and light smell. Therefore, using of fermented semi-finished product in the production of gluten free bread, provides improvement of physico-chemical and organoleptic indices of ready product.

4.3. Impact of fermented semi-finished product on air producing and air capturing capacity

The quality of ready products depends on the volume of the dough's size during storage, which in turn relates to the air producing ability and air capturing capacity of the dough.

Impact of gluten free fermented semi-finished product on rheologic characteristics of dough (air producing and air capturing capacity, dough rising) is shown on Table 3 and Fig. 8.

It is shown that using of gluten free fermented semi-finished product increases the air producting and air capturing ability of dough in the process of storage, which should be reflected positively on the quality of the bread. Therefore, the use

of gluten free fermented semi-finished product containing enzymatic microflora rich with heteroenzymatic lactic acid bacteria and active yeats, minerals and vitamins, accelerated air producing process due to active growth of bacteria and yeast.

Table 3.

Rheological features of dough for gluten free bread

Characteristics of indices	Value of dough indices (for gluten free bread)	
	control – dough without fermented semi-finished product	Experimental sample-dough with fermented semi-finished product
Dough rising, mm	7,9	13,4
Common volume of removed CO_2, cm^3	528	602
Volume of CO_2 bound by dough, cm^3	504	588
Volume of lost CO_2, cm^3	24	14
Air retention coefficient %	95,5	97,7
Duration of leavening (fermentation) min.	90	
Temperature of the dough, ^{0}C	30,0	
Mass of the dough, g	315,0	

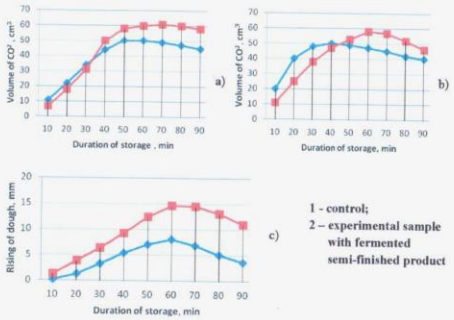


Figure. 8 Air production of dogh (a), air capturing (b) and the dynamic of dough rising (g) during storage.

4.4. Influence of fermented semi-finished product on microbiological stability of bread during storage

One of the most important tasks in the technology of the gluten free bread production is increasing of its sustainability. It is known that the quality of microbial contamination of basic raw product has a significant influence on the development of mold and potato disease.

For the purpose of raising the microbiological safety of gluten free bread, we offered using fermented semi-finished product which contains organic acids (milk and acetic acid), which reduces the development of potato rod Bac.Mesentericus. Organic acids play the role of preservatives. In addition, lactic acid bacteria cause liquefaction of the dough, which ensures moisture reduction by 2-3% and thus increase the sustainability of bread against mold.

The following method has been developed to examine the influence of fermented semi-finished product on the intencity of producing mold in bread: bread taken from oven was packaged up by sterile paper and put into sterile box for cooling. Then we cut the pieces of 4,5 x 7.5 cm in size and thickness 0,3-0.4 cm in steriled conditions. The pieces of bread was put on Petri dishes.

For the infection of bread we took bread samples and prepared water suspension of clean culture of Penicillum Chryzogenum, for which the biomass of pure culture from the taste-tube was transferred into 1 ml sterile water and was suspended. Then we inserted biomass with microbiological needle into the bread slices 3-3 injections. The incubation of Petri dishes was done in the thermostat at 25^{0}C temperature condition and growth of culture was observed. As a result of the study, it was found that on the bread sample N1 prepared from the 52% humidity dough, mold appeared after 24 hours; on sample N2 (with humidity - 49%) - after 36 hours, that indicates a positive impact of humidity reduction.

In the same way, we carried out the experiments to reveal potato disease, for which we added bread crumb containing spores of Bac. Subtilis with amount of 1 percent per gluten free flour masses. By the sample laboratory bakings it was established that unpleasant odor in control sample appeared after 18 hours, and sticky bread crumb after 24 hours. Potato disease did not appear in samples prepared using fermented semi-finished product. Therefore, we must conclude that the use of fermented semi- finished product, in the gluten free bread production, completely reduses the development of potato rod spores and increases the antagonistic activity of Bac. Subtilis. The fermented semi-finished products positively affects the growing of microbiological safety of bread.

4.5. Influence of fermented semi-finished product on the nutritional value of bread

In the process proecting of bakery composition for bread additionally to the providing of bread quality, the problem of nutritional value of bread must be also taken into consideration, to ensure that people being on gluten free diet suffer the deficiencies of various nutrients.

Table 4.

Content of the main components in gluten free bread

Name of indices	Index values (calculated on g / 100g of gluten free bread)	
	Control – brad without fermented semi-finished product	Experimental sample – bread with semi-finished product
proteins, g	6,4	10,1
lipids, g	2,3	3,2
carbohydrates, g	37,2	32,7
Food fibers, g	0,9	3,8
ashes, g	0,7	1,2
Energetic value, kcal /kjoule	195/818 kjoule	200/839 kjoule

Table 5.

Content of vitamins micro- and macroelements in gluten free bread

Name of indices	Index values (calculated on g / 100g of gluten free bread)	
	Control – brad without fermented semi-finished product	Experimental sample – bread with semi-finished product
Vitamins, mg/100g		
Vitamin A	0,0058	0,0072
Vitamin B1	0,092	0,096
Vitamin B2	0,050	0,058
Vitamin E	0,56	0,61
Mineral substances, mg/100g		
Na	210,0	234,2
K	128,1	139,6
Ca	36,6	50,7
Mg	21,2	28,4
Zn	0,064	0,078
Fe	1,8	3,2
Mn	0,378	0,408

Based on the conducted research it is established, the use of fermented semi-finished products provides enrichment of chemical composition of gluten free

bread with valuable food components. By comparing of control and experimental samples it was shown that the amount of food fibers is significantly increased in the bread by using fermented semi-finished product; B_1 vitamin – by 0,004 mg /%; B_2 – by 0,008 mg /%; From mineral substances: potassium – by 24,2 mg /%; Calcium – by 14,1 mg /%; Magnesium by 7,2 mg /%; Iron – by 1,4 mg /% (Tables 4 and 5).

4.6. The processing of the technology of gluten free bread

Based on the researches carried out, the preparation methods of gluten free bread are processed:

- Together with traditional, use of local gluten free raw material and structural substances without fermented semi-finished product;
- Use of both raw materials and structural substances with fermented semi-finished products.

4.6.1. The technology of gluten free bread production using fermented semi-finished products

Preparation technology of gluten free bread provides use of: for rice flour, buckwheat flour, corn starch, nutritional supplements - amaranth or pea flour, garminated soybean flour, orange pressing powder, medium mineralization 5-10 g / cm^3 carbonate mineral water, pressed yeast, salt, vegetable oil, for the preparation of dough, dough kneading, raising, molding, storing, baking. The table 6 represents the recipe of the gluten free bread with high-biological value for people with celiac disease.

Table 6.

Recipe for gluten free bread

№	Characteristic of raw product	Amount of raw product kg (calculated on 100 kg flour)
1	Rice flour	45,0
2	Buckwheat flour	25,0
3	Corn starch	15,0
4	Amaranth or peas flour	8,0
5	Food fibers (powder of apple or orange extraction)	2,5
6	Pectin	1,5
7	Germinated soybean flour	3,0
8	Pressed yeast	3,0
9	Salt	1,5
10	Vegetable oil	3,0
	Sum	107,5

To prepare dough, pressed yeast, vegetable oil, mineral water, gluten free flour composition consisting of rice flour, buckwheat flour, corn starch, food fiber, pectin, amaranth or pea flour, germinated soybean flour and salt are loaded into the bowl. All ingredients are mixed to each other and are kneaded till obtaining homogeneous structure at initial temperature 30°C. The temperature and the amount of mineral water is calculated by considering the temperature and humidity (52,0%) of dough. After kneading, the dough is loaded in the molds and placed into the storage bar in the condition of 75-80% relative humidity of air and 38-40°C temperature. Storing lasts about 40 - 55 minutes, after which the product is backed on 210°C during 18 - 20 minutes. After baking the bread is cooled and packaged up.

4.6.2 The technology of gluten free bread production using fermented semi – finished product

Preparation of fermented semi-finished product and dough for gluten free bread is done according to regimes represented on Table 7.

For the preparation of dough, water, part of the yeast, vegetable oil are added to the risen fermented semi-finished product. Then gluten free flour composition, food fibers, pectin, salt are added to the dough and kneaded till getting homogenious composition on the temperature 28-30°C. The temperature and amount of water are calculated by considering the tempereture and humidity of the dough. After kneading, the dough is placed into the molds and stored on 38-40°C at a storage bar on the condition of 75-80% of the relative humidity of the air during 40-55 minutes. Baking process is done on the temperature of 210°C for 18 - 20 minutes.

Table 7.

Regime of dough preparation using fermented semi-finished product

Characteristics of process indices	Values of indices of process preparation	
	Gluten free fermented semi-finished product	Dough, prepared from gluten free fermented semi-finished product
Temperature, °C	30 ± 1	29 ± 1,0
Acidity, in dergees	12,0	5,5 ± 1,0
Humidity, %	65,0 ± 1,0	48,0 ± 1,0
Duration: - rising, hours	8 ÷ 10	-
- storage, min.	-	40 – 55

Basic Conclusions

Complex reasearches have been conducted, based on the results of which, posibility of preparing gluten free bakery products is scientifically substantiated and experimentally determined, using local raw material for dietotherapy of people with celiac desease

1. The local gluten free raw products are selected: soybean, green peas, amaranth, topinambur, their chemical composition, biological and technological properties are learned. The results indicate high nutritional and biochemical value of the raw products
2. The study of the germination process of enzymatic modification of the selected gluten free cereal and leguminous crops has been conducted. As a result of experiments, the optimal technological parameters of the process are determined to ensure maximum accumulation of micronutrients.
3. The mineral waters of Georgia are used for the optimization of germinating process of raw material and the best results are achieved by using Tskaltubo's weak radon chloride-hydrocarbon-sulfate mineral water. It was found that, the amount of calcium, magnesium, sodium, potassium and phosphorus, microelements and vitamins increased significantly using mineral water to compare with the usual potable water. Particularly noteworthy is the increasing the amount of vitamin C, which was practically not found in the initial raw material.
4. Structural agents are selected for gluten free bread and their impact on its quality is examined. In flour composition, instead of extruded starch, which has low water absorption capasity, corn starch and citrus fruit processing products - food fibers and pectin with high esterification degree are used. Citrus fibers and pectin water absorption capacity is 2,2 to 2.7 times higher than the same indices of extruded starch. Its replacement with citrus food fibers and pectin provides the improvement of the dough structure, the physico-chemical (special volume, compressive) and organoleptic parameters of gluten free bread quality.
5. The influence of natural citrus fibers and pectin on the rheological properties of dough (dynamic viscosity), physico-chemical (acidity, compression) parameters of bread quality and organoleptic indices have been studied. By adding of 1,5% citrus fibers to the recipe mixture, viscosity of the dough approached to the control sample, the volume of bread became higher than the control. Adding of fibers to the composition led to the increase of titrated acidity of the product from 0.3 to 0,5 degrees, which led to the formation of a more pronounced taste of finished products. The bread compression has

increased. The best organoleptic indices were obtained using citrus food fibers from 0,9% to 1.5%.

Adding of pectin in flour composition positively reflected on the acidity and compression of ready products. Increasing of the amount of pectin caused increasing the bread acidity. Using of 0.5% pectin increases bread acidity 3 times to compare with control. Experiments have shown that optimal dose of citrus pectin is 1,0%.

6. The technological process scheme of fermented semi-finished product is developed. To prepare the fermented semi-finished products, we have selected and researched the local gluten free raw materials – amaranth and peas flour, germinated soybean flour. Instead of water, the use of carbonated mineral water is intended to intensify fermentation processes. Soybean milk-based product, which contains lactose and bipidobacteria, is used to stimulate acid fermentation. This recipe ensures more intensive acidity accumulation, which has a positive effect on taste properties and provides microbiological stability.
7. The influence of fermented semi-finished product has been studied on air producing and air capturing capacity of dough. The use of gluten free fermented semi-finished product containing fermenting microflora rich in heteroenzymatic lacto bacteria and active yeats, minerals and vitamins, accelerated the air producing capacity of dough at the expense of active growth of bacteria and yeast.
8. The influence of fermented semi-finished product has been studied on the physico-chemical indices of gluten free bread. Using a fermented semi-finished product, acidity of ready product increased 9,7 times, compressibility of bread crumb - 2,2 times, specific weight by 30%, and porosity by 13.8%. Organoleptic indices have also been improved. The obtained sample had a right form, glossy, smooth, sharp bark, porosity thin and equal, taste is characterized by a little pleasant acidity.
9. The effect of fermented semi-finished product on the microbiological stability during storage of bread has been studied. It was established that the use of fermented semi-finished product in the gluten free bread completely reduces the development of potato desease and increases the antagonistic activity of Bac. Subtilis. The fermented semi-finished product has a positive effect on the microbiological safety of the bread.
10. The influence of fermented semi-finished product on the nutritional value of gluten free bread has been studied. Based on the research conducted, the use of fermented semi-finished products provides enrichment of chemical composition of gluten free bread with valuable food components. The amount

of food fibers has increased significantly in bread; B1 vitamin - 0,004 mg /%; B2 - 0,008 mg /%; From mineral substances: potassium - 24,2 mg /%; calcium - 14,1 mg /%; magnesium - 7,2 mg /%; iron - 1,4 mg /% comparing to control.

11. For people suffering from celiac disease, the high-bio-valuable bread recipes have been developed and:

1) Gluten free bread technology without fermented semi-finished product
2) Gluten free bread technology using fermented semi-finished products.

List of published works

1. Silagadze M. A., Pruidze E. G., Gachechiladze S. T., Khvadagiani Kh. B. " Scientific and practical substantiation of the technology of non-yeasted bread production"/ Materials of International Scientific-practical Conference " Science and innovative technologies", Akaki Tsereteli State University, Kutaisi, 28-29 November, 2014, pp.165-167.
2. Silagadze M. A., Khvadagiani Kh. B., Gachechiladze S. T., Pkhakadze G. N. Actual trends in the development of the assortment of marmalade-pastille products in Georgia from the position of healthy nutrition / Proceedings of the International Scientific and Practical Conference "Achievements and prospects for the development of the confectionery industry", National University of Food Technologies, Kiev, Ukraine, 2015, pp. 18-22.
3. Pruidze E., Khutsidze Ts., Dzneladze E., Gachechiladze S., "Therapeutic - Prophylactic Wheat Bread Technology Using Topinambur"/ Materials of International Scientific-Practical Conference "Innovative Technologies for the Functional Purpose Food Production", Akaki Tsereteli State University, Kutaisi, Georgia, April, 2015, pp. 166-168.
4. Gachechiladze S.T., Silagadze M.A., Pruidze E.G., Khutsidze Ts.Z., Berulava I.O., Sugar cookies of the new generation - a product of a functional purpose based on local raw materials / Proceedings of the international scientific - practical conference " , Achievements and prospects for the development of the confectionery and bakery industry ", National University of Food Technologies, Kiev, Ukraine, 2016, pp. 79-81.
5. Kh. Khvadagiani, S. Gachechiladze, G. Pkhakadze, M. Silagadze "Research of Georgian soy and its processing products with the prospect of use in bakery production" / Proceedings of International Scientific and Practical Conference "Modern Engineering Technologies and Environment", Akaki Tsereteli State University, Kutaisi, Georgia, 19-20.05.2016, pp. 284-286.
6. M. Silagadze,E. Gamkrelidze, S. Gachechiladze,M. Khurtsidze, G. Pkhakadze, Development Of New Generation "Live" Foods With Rational Use of Raw

Materials From Georgian Resoerses / Scientific enquiry in the contemporary world: Theoretical basics and innovative approach, San Francisco, California,USA, 26_8, 2016, pp. 238-243.

7. M. Silagadze, E. Pruidze, .Gachechiladze, M. Khurtsidze, G. Pkhakadze, Development of functional dietary product on the base of complex use of local plant raw material / Scientific enquiry in the contemporary world: Theoretical basics and innovative approach, San Francisco, California,USA, 26_8, 2016, pp. 244-249.
8. M. Silagadze, E. Pruidze, S. Gachechiladze,G. Pkhakadze, Kh. Khvadagiani, Obtaining and a comprehensive study of highly bioavailable functional food additives based on Georgian soya varieties /Annals of Agrarian Science, Tbilisi, 2017, pp. 356-360.
9. M. Silagadze, S. Gachechiladze , E. Pruidze, G. Khetsuriani, Kh. Khvadagiani, Development of new – generation dietary bread technologies by using soya processing products, Georgian soya varieties/ Annals of Agrarian Science, Tbilisi, 2017, pp. 177-180.