Biotechnological Aspects of Iodine Enrichment of Bakery Products

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Abstract. In case of potential radiological contamination of territories, preventive intake of iodine-containing products before the arrival of iodine radionuclides is effective. The paper presents the results of the influence of changes in the recipe composition of the bakery product, namely the use of the additive iodocasein on the physico-chemical and organoleptic characteristics of bread. The use of iodocasein for bread enrichment is justified. The influence of technological parameters on the preservation of the iodine trace element in bread is investigated. Doses of iodine-containing additives are calculated in the technological process. It is proved that the iodine in bread is preserved in the product for 90 hours. The nutritional value of the developed bread recommended for preventive nutrition is evaluated.

1 Introduction

The relevance of the research topic is accumulated by the following circumstances. Firstly, with potential radiological contamination, the effect of iodine prophylaxis is achieved with the preventive intake of iodine-containing products before the receipt of iodine radionuclides, secondly, the company's participation in tenders for the supply of bakery products to educational organizations requires additional efforts to comply with the quality of products, including the content of trace elements, thirdly, the export potential of food products directly depend on the implementation of the principles of Hazard Analysis and Critical Control Points.

To overcome iodine deficiency in nutrition, individual, group and mass iodine prophylaxis tools are used. Mass iodine prophylaxis is the most effective and economical method of replenishing iodine deficiency and is achieved by introducing iodine salts into the most common foods: table salt, bread, water [1]. The "dumb" method of prevention suggests that consuming iodine-enriched foods, the consumer may not pay attention to this aspect.

To date, many methods have been developed for the preparation of iodine-enriched bread using seaweed, fucus, iodosin, an additive based on iodocasein.

As Louise Brough notes, Fortification strategies to improve iodine intake have been adequate for school-age children (SAC); however, often, iodine deficiency remains for

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breastfeeding women and their infants. Daily supplementation with iodine is not an ideal strategy to overcome deficiency. [2]

Hypothesis The development of technology for enriching bakery products with iodine will solve the problem of iodine deficiency conditions of the population, ensuring the intake of iodine into the human body with food.

2 Materials and methods

The methodological basis of the research is the categorical apparatus of product quality management; methods of analysis and synthesis, structural and functional method of system research, monographic on the technology of bakery products production were used to solve the tasks.

To determine the physico-chemical parameters, standard methods were used: the mass fraction of moisture was determined according to GOST 5900-2014.

The Technical Regulations of the Customs Union TR CU 021/2011 "On fOod Safety" (as amended on July 14, 2021) prescribes the following methods of identification of food products: by name, visual, organoleptic, analytical.

As technological criteria for enriching bread and bakery products with iodine, the following are taken into account: compatibility of the iodine-containing preparation with the prescription components of the products; manufacturability (simplicity, ease of use); comprehensive study of the effect of the drug on the quality of bread, dough properties, indicators of microbiological safety of bread; safety of iodine during the technological process of production and storage of enriched products [3]. The safety of iodine in the finished product: after proofing, baking and storage is due to the methods of preparing the dough: accelerated, straight dough, and sponge dough.

All raw materials used for the production of the Coastal loaf comply with SanPiN 2.3.2.1078 (clause 3.6), are authorized by the Rospotrebnadzor authorities and are accompanied by documents confirming its quality and safety.

Plant raw materials are accompanied by a declaration on the use of pesticides in its production, storage and transportation. The content of the residual amount of pesticides should not exceed the levels established in GN 1.2.1323.

The use of raw materials obtained with the use of genetically engineered organisms is not allowed.

Both deficient and excess iodine intakes may precipitate in adverse thyroidal events. To use iodine to block the thyroid gland during radioactive exposure, accurate readings are necessary [4].

3 Results and discussion

In the scientific literature, certain attention is paid to the technologies of fortification of food with trace elements [5], magnesation and iodization [6].

The use of iodized salt and iodized yeast is the most preferable, since their use is similar to the use of the main prescription components of bakery production, i.e. it does not require additional technological operations for preparation and dosing. However, the safety of iodine during processing is one of the most important criteria for enrichment, confirming or refuting its feasibility and effectiveness. Until 2018, in the Russian Federation, the enrichment of food salt with potassium iodide (KI), Iodine in such salt lasts only three to four months and instantly disappears when heated to 30 °C; the new GOST R 51574-2018 for salt, which requires enrichment exclusively with potassium iodate (KIO_3).

Comprehensive studies show that the introduction of iodocasein into the recipe of bread baked from wheat flour of the highest grade significantly improves the quality of finished products in terms of specific volume, shape stability, porosity, structural and mechanical properties of the crumb, including during storage.

The results of studies of the physico-chemical and rheological properties of the dough and gluten confirm this assumption. Farinogram data show that iodized salt increases the formation time of the dough by 25%, and its elasticity and extensibility – by 8% compared to the control sample. Such indicators as stability and dilution of the dough were significantly influenced only by the addition of salt iodized by KIO_3. The stability of the dough in this case increased by 60%, and its dilution decreased by 33%. The same additive significantly strengthened the structure of the dough, as evidenced by an increase in excess pressure, the deformation energy of the dough while reducing the extensibility index and the average abscissa at the break obtained on the alveograph [7].

The observed changes are due to the presence of active potassium iodate in the iodized salt, which is involved in the oxidation of the structural components of the dough, primarily gluten, as a result of which it is strengthened due to the formation of disulfide bonds in the structure of protein fractions.

Recently, when using various enriching additives, much attention has been paid to the indicators of hygienic and microbiological safety of food products. Since the most common diseases of bread are mold and potato disease, salt iodized with KIO_3, has a significant effect on the growth of microflora – pathogens of potato disease Bacillus subtilis and mold fungi Penicillium.

For research, samples of bread without salt were prepared (control) with the addition of 1.5% non-iodized table salt according to GOST 51574-2018 with the addition of 1.5% salt iodized by KIO_3. During storage for 7 days, the growth of colonies of Bacillus subtilis and mycelium of Penicillium mold fungi was studied. Therefore, it can be concluded that table salt and salt iodized with KIO_3reduce the growth of bacteria on bread samples two and five days after plating, as evidenced by a decrease in the area of damage to the surface of bread by 25 and 38%, respectively. The depressing effect of salt on the development of Penicillium mold fungi has also been established, and the diameter of the mycelium decreases in bread samples with ordinary salt by 6-17% (during 7 days of storage), in samples with iodized salt – by 12-28%.

The scientific literature describes the management of product quality control at the bakery enterprise, including: control of the production process of a loaf of a mixture of rye and wheat flour using the additive "Iodocasein" in relation to each technological operation; determination of possible risks of contamination of raw materials and finished products; determination of control critical points of production and ensuring the safety of finished products; definition of requirements for methods of control and formation of instructional and methodological base at the enterprise; establishment of requirements for the maintenance and storage of control documentation; development of sanitary and anti-epidemiological measures to ensure product safety; determination of compliance of the sanitary condition of production with the requirements of regulatory documentation; requirements for personnel responsible for the organization and conduct of production control [8]

The Institute of Food Technologies of Chisinau has established a high preservation of iodine both during the technological process of bread production using iodine-containing additives and during storage (from 70 to 95%). The iodine content after three days of storage changed slightly in comparison with the initial content. The greatest loss of iodine is found in bread with the addition of bran – this bread has the highest acidity of the crumb (0.42% in terms of lactic acid). Table salt contributes to the preservation of iodine, and organic acids reduce it [9].

The complex of studies conducted on the enrichment of bread with iodine allowed scientists to develop and approve, in accordance with the established procedure, "Instructions for recipes for bakery products on the interchangeability of raw materials" [10], according to which iodized food salt with an iodine content of 40±15 μg/g of salt and a two-year shelf life (manufacturer - CJSC Valetek Prodimpeks, Russia) can be used in the production of bakery products instead of ordinary table salt.

When using highly stable KIO_3 iodized salt with an iodine content of 40±15 μg/g for bread enrichment, finished products with an iodine content of 20-35 μg/100 g of bread are obtained, which makes it possible to provide 30-50% of the average daily norm of the recommended amount of this micronutrient when consuming 250 g of bread [10].

When enriched with iodine, preference is given to a non-sugar method of bread production, since when the acidity of the dough is 0.4% or higher (in terms of lactic acid), iodine is lost.

The recommended dosages of iodine-containing additives in the flow diagram ensure the iodine content in 100 g of bread in accordance with the calculations (excluding technological losses) – 55.0 and 44.0 μg when using salts iodized K1 and KIO3,44.0 μg - when adding iodized yeast and 45.0 μg - when adding iodocasein [11].

In accordance with TU 9229-001-79899185-2007 "Complex food additive "Iodocasein" the total iodine content in the product should be from 7 to 10% of the total weight of iodocasein, molecular iodine - no more than 0.5%.

It should also be noted the safety (non-toxicity) of iodine-containing additives. According to WHO experts, eating up to 1100 μg of iodine per day is safe [12].

Negative effects due to excessive iodine intake have been described in the scientific literature [10].

The analysis of the declared iodine content in the studied additives entering the Russian bread market, manufacturers' recommendations on their dosage, calculated data on the iodine content in baked products indicates that the estimated content of the trace element in the average daily portion of bread 200-250 g is 70-140 μg, i.e. does not exceed both the physiological and the maximum permissible non-toxic level [14]. Information about the iodine content should be reflected on the label of the bakery product.

4 Author's development of an enriched bakery product

After analyzing the bakery products produced by the Surgut Bakery, it was decided to introduce iodocasein into the recipe of the bakery product – the Coastal loaf.

A Coastal loaf weighing 0.2 kg is made from rye-wheat flour in accordance with GOST 31807-2018. To enrich the Coastal loaf, the additive "Iodocasein" was used according to TU 10.51.53-001-79899185-2017. Table 1 shows the production recipe of a loaf enriched with iodocasein.

Table 1. Production recipe for 100 kg of finished product enriched loaf

Name of raw materials, kg	**Dough**
Wheat flour of the first grade	60.5
Medium rye flour	12.6
Yeast suspension	7.7
Salt solution (p-1.2 kg/dm)	3.9
Sourdough (K-25 deg)	3.5
Pregelatinized flour	13.7
Sunflower oil	2.3
Water	21.2
Iodocasein, gram	0.5

Table 2 contains the parameters of the technological process for a loaf enriched with iodocasein

Table 2. Parameters of the enriched loaf technological process

Parameters	Value
Moisture, %	44.0
Initial temperature, °C	28-29
Final acidity, deg	5.0
Duration of fermentation, min	50
Weight of the dough piece, g	240
Duration of proofing	45-55
Baking duration, min	18-20
Baking temperature °C	220-230

When choosing the amount of the introduced additive, it was assumed that in order to ensure food safety, the content of the additive in the finished product should not exceed 20-30% of the recommended consumption. For the adult population, the daily iodine requirement is 150 μg. [14].

The iodine content in the daily bread ration should be within 30-45 μg of iodine with an average daily bread consumption rate of 350 g [15].

The differences in the technological parameters of the preparation of a loaf without and with the addition of iodocasein are presented in Table 3

Table 3. Technological parameters for the preparation of bread samples

Operation name	Characteristics of modes	
	Control sample of a loaf	Prototype of a loaf
1. Iodocasein	–	+
2. Preparation of salt solution, filtration	+	+
3. Preparation of yeast suspension in water	+	+
4. Dough kneading: Duration, min Temperature, °C Speed, rpm	 15 30 120–170	 15 30 120–170
5. Fermentation: Duration, min Temperature, °C Punching after 60 minutes	 180 30 ± 2 2 times 5 min	 120 30 ± 2 1 time 5 min
6. Dough forming: Weight of the dough piece, g	 550	 550
7. Proofing: Duration, min Temperature, °C	 70 37 ± 2	 60 37 ± 2
8. Baking: Duration, min Temperature, °C	 40 220–230	 40 220–230

The differences in the production scheme of the prototype are in the fermentation time of the dough, which is 60 minutes less than for the control sample (120 and 180 minutes, respectively), and the proofing time – the prototype has 10 minutes less than the control (60 and 70 minutes); the technological process is reduced by 70 minutes.

In the experimental and control samples of bread, organoleptic, physico-chemical and microbiological parameters were determined after baking the products and after 90 hours from the moment of manufacture. Bread samples packed in shrink wrap were examined for

the presence of yeast, mold and rope spoilage of bread. The results of the experiment are shown in Table 4.

The moisture content of the bread crumb was determined by drying the products at a temperature of 130 °C for 40 minutes.

Titratable acidity was determined by titration with 0.1 NaOH solution in the presence of 1% alcohol solution of phenolphthalein.

The porosity of the crumb characterizes the consumer properties of bread and its digestibility. Porosity was determined by the average mass of five probe samples using the Zhuravlev device [16].

The determination of the mass fraction of iodine in bread was carried out according to GOST 26185-84 "Seaweeds, sea-grasses and its processed products. Methods of physical and chemical analysis" by the colorimetric method.

Table 4. Physical and chemical parameters of loaf samples

Sample name	Bread indicators						Iodine retention 90 hours after baking, % of added
	After baking			90 hours after baking			
	crumb moisture, %	crumb acidity, deg	crumb porosity, %	crumb moisture, %	crumb acidity, deg	crumb porosity, %	
Coastal Loaf control	41.1	3.3	74.8	40.4	3.2	74.4	-
A loaf enriched with iodocasein	41.2	2.0	73.4	39.9	1.8	72.0	95

Analysis of the data obtained indicates that the introduction of iodine-containing preparations does not worsen the normalized parameters of the loaf, including humidity, acidity and porosity of the crumb compared to the basic version.

A high level of iodine preservation of 90-95% has been proven in the technological process of production of the Coastal loaf using iodocasein and during storage. The composition of iodine after three days of storage drops insignificantly in comparison with the initial level.

It follows from scientific sources [17] that the use of iodine-containing additives prevents rope spoilage of bread and mold formation during storage, indicated in Table 5.

Table 5. Microbiological indicators of a long loaf enriched with iodcasein

Product	Indicator	Contamination during storage		
		24h	48h	72h
Coastal Loaf with iodocasein	Yeast, CFU/g	ND	ND	ND
	Mold, CFU/g	ND	ND	ND
	Definition of rope spoilage of bread	ND	ND	ND

Iodocasein, unlike other additives, does not worsen the specific volume of the bakery product, has a positive effect on the crumb compressibility indicators and is characterized by minimal iodine losses during the technological process – less than 2% of the total content.

5 Conclusions

A technology has been developed for enriching bakery products with iodine using Iodocasein, which contributes to a significant reduction in thyroid diseases in iodine-deficient areas when consumed.

When iodizing products, age, gender, region of residence should be taken into account (iodine deficiency is expressed in mountainous and foothill areas (North Caucasus, Altai, Siberian Plateau, Far East), in the Volga region and Central Russia) and professional activity of the consumer. Methods of replenishing iodine deficiency should be carried out taking into account its digestibility and technical features of the preparation of products: iodine evaporates during heat treatment.

The technology of the enriched Coastal loaf has been introduced into production at the Surgut Bakery, which confirms the act of implementation.

References

1. Control of the program for the prevention of iodine deficiency diseases by universal salt iodization: Methodological guidelines, 56 (Moscow: Federal Center of State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia, 2001).
2. L. Brough, Improving Iodine Status in Lactating Women: What Works? Curr Nutr Rep (2022).
3. A. A. Lukin, Prospects for the creation of functional bakery products, Bulletin of the South Ural State University. Series: Food and Biotechnology, **3(1)**, 95-100 (2015).
4. V. Calcaterra, C. Mameli, V. Rossi, G. Massini, M. Gambino, P. Baldassarre, G. Zuccotti, *The Iodine Rush: Over- or Under-Iodination Risk in the Prophylactic Use of Iodine for Thyroid Blocking in the Event of a Nuclear Disaster* (2022).
5. D. S. Ushakov, V. V. Shepelev, Yu. O. Patlasov, Innovative technologies of modified starch production. IOP Conference Series: Earth and Environmental Science, **488**, 012032 (2020).
6. D. S. Ushakov, V. V. Shepelev, Yu. O. Patlasov, Marketing researches of the modified starch market and the technologies of its production. IOP Conference Series: Earth and Environmental Science, 422, 012128 (2020).
7. L. V. Donchenko, *Technology of functional food products: a textbook for universities, 2nd ed., revised and enlarged*, 176, (Moscow: Urait Publishing House, 2019).
8. N. O. Patlasov, O. Yu. Patlasov, HACCP and food safety management systems in the PDCA cycle of the process approach. Russian Journal of Social Sciences and Humanities, **16(3)**, 240–249 (2022).
9. L. V. Donchenko, *Technology of functional food products: a textbook for universities, 2nd ed., revised and enlarged*, 176, (Moscow: Urait Publishing House, 2022).
10. I. I. Dedov, G. A. Melnichenko, E. A. Troshina, N. M. Platonova, F. M. Abdulkhabirova, L. N. Shatnyuk, B. P. Apanasenko, S. R. Kavtaradze, M. I. Arbuzova, F. A. Dzhatoeva, *Iodine deficiency is a threat to the health and development of children in Russia: National report*, 124 (2006).
11. Enriched bread with Iodocasein. The website of Ural Ingredient LLC, https://www.uraling.ru/o-kompanii.
12. C. Thompson, Dietary recommendations for iodine around the world, IDD Newsletter, **18(3)**, 38-42 (2002).
13. P. Donega, M. Gallerani, G. B. Vigna, R. Fellin, Reversible hyperthyroidism and cardiomyopathy caused by the consumption of iodocasein, Am J Med Sci., **320(2)**, 148-50 (2000).

14. Recommended levels of consumption of food and biologically active substances: Methodological recommendations, 36 (Federal Center of State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia, 2004).
15. G. A. Gerasimov, N. M. Mayorova, A. A. Shishkina, N. Yu. Sviridenko, A. N. Nazarov, G. F. Alexandrova, G. A. Kotova, S. A. Butrova, M. I. Arbuzova, B. P. Mishchenko, I. I. Dedov, Experience of using iodized bread for the prevention of endemic goiter in a region with moderate and mild iodine deficiency. Problems of Endocrinology, **43(2)**, 21-24 (1997).
16. GOST R 55972-2014 Bakery products. Receipt and technological instruction. General requirements for lay out, development and composition; Approved and put into effect by the Order of the Federal Agency for Technical Regulation and Metrology dated March 17, 2014. N 160-st.
17. P. P. Ershov, Collection of recipes for bread and bakery products, 13th ed., 208 (St. Petersburg: Profi, 2018).