The use of topinambur (Jerusalem artichoke) syrup to improve the nutritional value and quality of bakery products

Irina Tyurina*, *Irina* Peshkina, *Khachatur* Baluyan, *Elena* Tkachev and *Pavel* Shcherbakov

Federal State Autonomous Scientific Institution "Scientific Research Institute for the Baking Industry", 107553 Russia, Moscow, Bolshaya Cherkizovskaya street, 26A

Abstract. The paper analyzes the effect of inulooligosaccharide syrup made from topinambur (Jerusalem artichoke) in an amount of 5, 10, and 15% by flour weight on organoleptic, physical and chemical quality indicators, nutritional value and storage stability of bakery products made from wheat flour and a mixture of wheat and rye flour. Bread samples from wheat flour were made by straight dough, sponge and dough, and quick dough methods, and samples from a mixture of wheat and rye were made using thick rye sourdough. Bakery products made by different methods with inulooligosaccharide syrup added in the amount of 10 and 15% showed a brighter color of the crust with a sweet flavor compared to the control sample and bakery products made with the addition of 5% syrup. The mass fraction of sugar in bakery products was found to increase on average 2–7 fold in comparison with that in the control sample. The lowest rate of staleness was observed in products made with syrup added in the amount of 15%, baked from wheat flour by the sponge and dough method and those made from a mixture of wheat and rye flour using thick rye sourdough; it amounted to 147 g/day and 140 g/day, respectively. The actual content of inulin in bakery products made with the addition of inulooligosaccharide syrup was 4.9 g for products made from wheat flour, and 5.3 g for products made from a mixture of wheat and rye flour. The daily physiological need for inulin averages 50% for people who consume 100 g of bakery products made with the studied syrup added; therefore, these products can be classified as enriched and functional.

1 Introduction

A significant trend in the development of the modern food industry is the expansion of the production of functional food products supplemented with food additives of natural origin (plant extracts, fruit and vegetable powders, dietary fiber, etc.). Fructose-glucose syrup and inulin are natural additives used in the food industry. Domestic producers currently use imported products; therefore, manufacturing of import-substituting products is of high relevance. IstAgro Don LLC has developed inulooligosaccharide syrup from topinambur,

* Corresponding author: i.tyurina@gosniihp.ru

which contains 70–80% inulin in terms of dry matter. Inulin is considered a prebiotic and refers to functional ingredients; it is a polysaccharide of fructose residues linked by β-2,1 glycosidic bonds [1].

Inulin is not absorbed in the stomach and small intestine, but it is fermented by the microflora of the large intestine; therefore, regular consumption of inulin as part of food products can improve human health. It helps normalize the blood sugar level, decrease the level of cholesterol and triglycerides, which prevents the development of arterial sclerosis, increases resistance to bacterial and viral infections of the digestive system, and normalizes metabolism [2]. Inulin exhibits not only physiological, but also technological functionality. It forms a creamy gel of a fat-like texture when contacts with water and thus mimics the presence of fat in dietary products, and imparts full taste and texture to the products.

An appropriate intake of inulin is 10 g per day [3]. One portion of a functional product contains from 15 to 50% of the daily need. A technological dosage may be increased, since inulin starts to improve the texture and taste at concentration exceeding 2% [4, 5].

In this regard, it is of current relevance to conduct studies to analyze the effect of inulooligosaccharide syrup made from topinambur on the quality, storage stability, and nutritional value of bakery products.

2 Materials and methods

The study employed conventional and special methods to assess the quality indicators of bakery products [6]. For baking, we used wheat flour of the first grade, medium rye flour, pressed baking yeast, table salt, inulooligosaccharide syrup, dry milk whey, and drinking water.

Crumbling of products was evaluated by ‘Method for determining the crumbliness of the crumb of a bakery product STP-1901’ developed at the Federal State Scientific Institution Research Institute of Chemistry and Chemistry. The method implies determination of the weight of crumbs of a slice of the pre-weighed bakery product with a thickness of 12.5 mm cut into 8 pieces after its exposure to dynamic loads. The slice is cut on the board into pieces with roughly equal area (one cut along and three cuts across the slice), and then the pieces are placed on a sieve installed in the U1-ERL laboratory plansifter. A total of 6 pieces of Belting cleaners (Ø25 mm rubber balls) are also placed in the sieve, and sieve vibration is performed for 60 s.

The rate of staleness was evaluated in compliance with GOST R 70085-2022 ‘Bakery products from wheat flour. Method for determining the degree of staleness. The method determines the loading force applied to a cylindrical crumb sample during its compression, followed by calculation of the crumb staleness value (with respect to density and moisture), which is used to assess the degree of staleness of the bakery product during storage. The rate of change in the crumb staleness value during the storage period is taken as the rate of crumb staleness.

The content of inulin was determined in accordance with the guide R 4.1.1672-03 ‘Guidelines for methods of quality control and safety of biologically active food supplements’ [7].

3 Results and discussion

Based on the calculation method, with regard to the regulated level of the inulin content in enriched products [8] (one portion of the product should contain 15 to 50% of inulin of the daily physiological need), we propose dosages of inulooligosaccharide syrup of 5, 10, and 15% by flour weight.

For evaluation of the effect of the studied syrup on quality and nutritional value, bakery products were made by different methods:

- from wheat flour by the sponge and dough method, straight dough method, and quick dough method;
- from a mixture of wheat and rye flour, using thick rye sourdough [9, 10]. The required amount of syrup was added during dough making. The control samples were bakery products made without the studied syrup.

Figure 1 shows bread samples made by different methods, with the addition of inulooligosaccharide syrup.

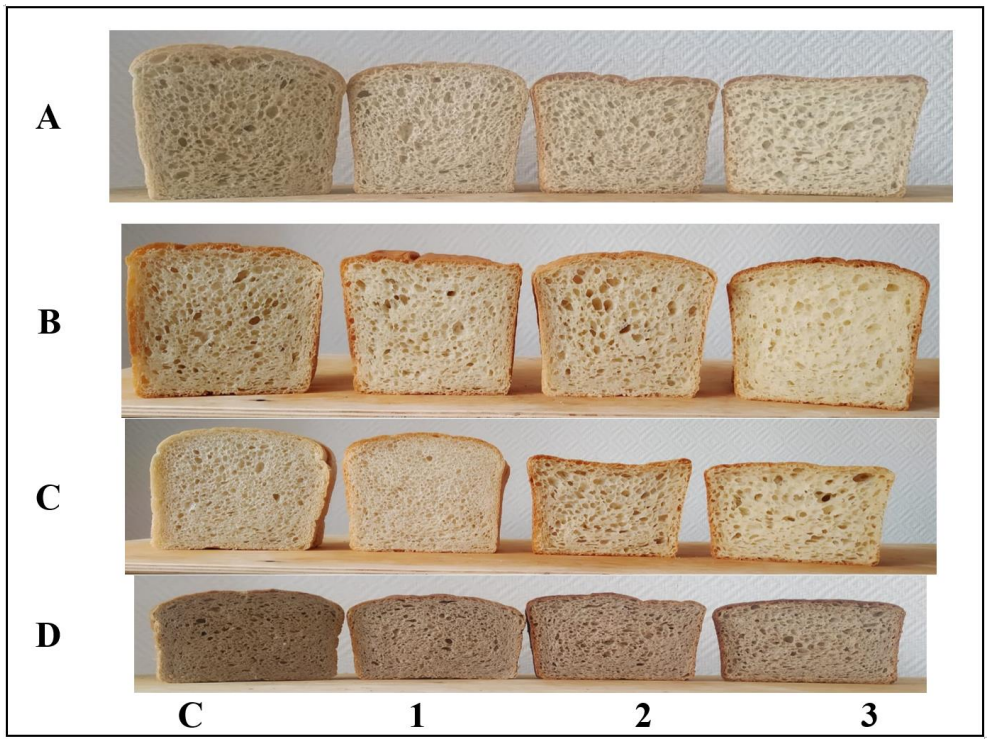

Fig. 1. Bakery products made by different methods from wheat flour: A – sponge and dough method; B – quick dough method; B – straight dough method; from a mixture of wheat and rye flour: G – using thick rye sourdough; with the addition of inulooligosaccharide syrup in the amount of 1 – 5%; 2 – 10%; 3 – 15% (by flour weight); C – control sample (without additives)

Bakery products made from wheat flour by the straight dough method and sponge and dough method with the addition of 5% inulooligosaccharide syrup showed a regular shape, smooth crust, developed uniform porosity, good crumb elasticity, and taste and smell peculiar to wheat bread. Bakery products made from wheat flour by the quick dough method exhibited a regular shape, rough crust, developed nonuniform porosity, good crumb elasticity, and taste and smell characteristic of wheat bread. Bakery products made from a mixture of wheat and rye flour were of a regular shape, with rough crust, developed uniform porosity, and taste and smell distinctive of wheat-rye bread.

Organoleptic quality indicators of bakery products made with the addition of inulooligosaccharide syrup are presented in Tables 1–2.

Table 1. Organoleptic quality indicators of bakery products made by the straight dough method and sponge and dough method with the addition of inulooligosaccharide syrup

Indicators	Bakery products made from wheat flour							
	straight dough method				sponge and dough method			
	Control	with syrup, % by flour weight			Control	with syrup, % by flour weight		
		5	10	15		5	10	15
Appearance of bread: shape	Regular, matches the bread baking form							
Surface	Smooth, no cracks or breaks		Concave, no cracks and breaks		Smooth, no cracks or breaks		Concave, no cracks and breaks	
Color	Pale	Light yellow	Light brown	Brown	Pale	Light yellow	Light brown	Brown
Crumb state: color	White				White			
elasticity	Good				Good			
doneness	Baked well, not moist to the touch				Baked well, not moist to the touch			
porosity	Developed, large, uniform, without voids and seals				Developed, medium, uniform, without voids and seals		Developed, large, uniform, without voids and seals	
Taste	Peculiar to wheat bread							
	No off-flavor		Presence of sweet flavor		No off-flavor		Presence of sweet flavor	
Smell	Peculiar to wheat bread							
Clumping when chewed	Absent							

Table 2. Organoleptic quality indicators of bakery products made from wheat flour by quick dough method and from a mixture of wheat and rye flour using thick rye sourdough, with the addition of inulooligosaccharide syrup

Indicators	Bakery products made from wheat flour by the quick dough method				Bakery products made from a mixture of wheat and rye flour using thick rye sourdough			
	Control	with syrup, % by flour weight			Control	with syrup, % by flour weight		
		5	10	15		5	10	15
Appearance of bread; shape	Regular, matches the bread baking form				Regular, matches the bread baking form			
Surface	Rough, no cracks or breaks				Rough, no cracks or breaks			
Color	Pale	Light yellow	Light brown	Brown	Light brown		Brown	
Crumb state: color	White				Grey			
elasticity	Good							
doneness	Baked well, not moist to the touch							
porosity	Large, developed, nonuniform, without voids and seals				Medium, developed, uniform, without voids and seals		Large, developed, uniform, without voids and seals	
Taste	Peculiar to wheat bread							
	No off-flavor		Presence of sweet flavor		No off-flavor		Presence of sweet flavor	
Smell	Peculiar to wheat bread				Peculiar to wheat and rye bread			
Clumping when chewed	Absent							

The organoleptic evaluation revealed that bakery products made by different methods and supplemented with the studied syrup in the amount of 10% and 15% by flour weight exhibited sweet flavor and a darker crust compared to the control and products that contained 5% syrup. The crust is of dark color due to a high concentration of sugars in bakery products that induce the formation of a significant amount of dark-colored melanoidins.

Physical and chemical indicators of the quality of bakery products supplemented with inulooligosaccharide syrup are presented in Tables 3–6.

Table 3. Physical and chemical indicators of the quality of bakery products made from wheat flour by the straight dough method with inulooligosaccharide syrup added

Indicator	Bakery products made from wheat flour by the straight dough method			
		with syrup, % by flour weight		
	control	5	10	15
Crumb moisture, %	45.6	45.6	45.5	45.2
Crumb acidity, deg	2.3	2.2	2.1	2.0
Crumb porosity, %	79.0	80.0	80.0	81.0
Mass fraction of sugar, %, in terms of dry matter	1.1	3.2	4.9	7.4

The study showed that the moisture content, acidity and porosity of the crumb of bakery products made by the straight dough method remained at the level of those in the control. It was found that the addition of 5–15% inulooligosaccharide syrup increased the mass fraction of sugar 3–7-fold compared to that in the control.

Table 4. Physical and chemical indicators of the quality of bakery products made from wheat flour by the sponge and dough method with inulooligosaccharide syrup added

Indicator	Bakery products made from wheat flour by the sponge and dough method			
		with syrup, % by flour weight		
	control	5	10	15
Crumb moisture, %	45.8	45.6	45.6	45.3
Crumb acidity, deg	2.2	2.2	2.2	2.1
porosity, %	79.0	81.0	82.0	81.0
Mass fraction of sugar, %, in terms of dry matter	2.6	4.2	5.6	8.2

The results of the study presented in Table 4 showed that the moisture content, acidity and porosity of the crumb of bakery products made by the sponge and dough method remained at the level of those in the control. It was found that the addition of 5–15% inulooligosaccharide syrup increased the mass fraction of sugar in bakery products 2–3-fold compared to that in the control.

Table 5. Physical and chemical indicators of the quality of bakery products made from wheat flour by the quick dough method with inulooligosaccharide syrup added

Indicator	Bakery products made from wheat flour by the quick dough method			
		with syrup, % by flour weight		
	control	5	10	15
Crumb moisture, %	45.2	45.0	45.1	45.1
Crumb acidity, deg	2.4	2.3	2.1	1.9
Crumb porosity, %	77.0	77.0	78.0	81.0
Mass fraction of sugar, %, in terms of dry matter	3.3	5.4	6.6	7.9

The results presented in Table 5 showed that the moisture content and porosity of the crumb of bakery products made by the quick dough method remained at the level of those in the control. The addition of inulooligosaccharide syrup increased the crumb acidity by 21%, which can be related to the reduced duration of dough fermentation, when the amount of organic acids accumulated in the dough is insufficient. It was found that the addition of inulooligosaccharide syrup increased the mass fraction of sugar in bakery products 2-fold compared to that in the control.

Table 6. Physical and chemical indicators of the quality of bakery products made from a mixture of wheat and rye flour using thick rye sourdough with inulooligosaccharide syrup added

Indicator	Bakery products made from a mixture of wheat and rye flour			
		with syrup, % by flour weight		
	control	5	10	15
Crumb moisture, %	45.3	45.1	45.0	45.0
Crumb acidity, deg	6.0	5.7	5.9	5.8
Crumb porosity, %	70.0	71.0	73.0	73.0
Mass fraction of sugar, %, in terms of dry matter	4.0	7.4	9.5	12.2

The results of the study presented in Table 6 show that the moisture content, acidity and porosity of the crumb of bakery products made by the sponge and dough method remained at the level of those in the control. It was found that the addition of 5–15% inulooligosaccharide syrup in increased the mass fraction of sugar in bakery products 2–3-fold compared to that in the control.

We studied the effect of inulooligosaccharide syrup on the staleness rate and crumb crumbling during storage of the bakery products. The results are shown in Figure 2 and Table 7.

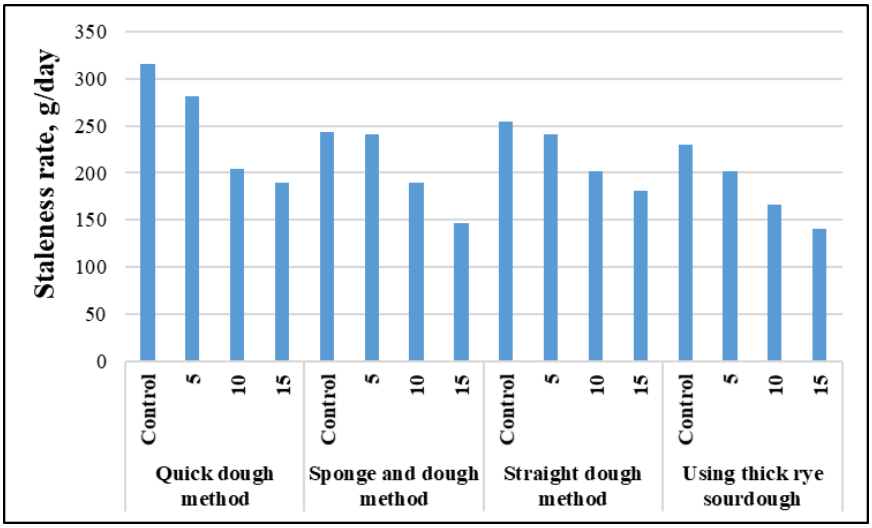

Fig. 2. Dynamics of the staleness rate of bakery products made by different methods with inulooligosaccharide syrup added

During storage of bakery products made by different methods with inulooligosaccharide syrup added, the staleness rate of all the samples decreased. It was found that 72 hours after baking, the staleness rate of bakery products made with syrup decreased on average by 37% compared to that in the control. The lowest staleness rate was found in the samples prepared using the inulooligosaccharide syrup in the amount of 15% by flour weight made from wheat flour by the sponge and dough method and from a mixture of wheat and rye flour using thick rye sourdough. Their staleness rate attained 147 g/day and 140 g/day, respectively.

Table 7. The value of crumb crumbling of the bakery products made by different methods with inulooligosaccharide syrup added

Baking methods	Bakery products supplemented with syrup, % by flour weight	Crumb crumbling, %	
		after 24 h	after 72 h
Dough method	control (without additives)	2.00	2.14
	5	1.87	1.98
	10	1.72	1.80
	15	1.6	1.67
Sponge and dough method	control (without additives)	1.87	1.90
	5	1.80	1.87
	10	1.50	1.56
	15	1.30	1.34
Quick sponge method	control (without additives)	1.80	1.90
	5	1.46	1.53
	10	1.31	1.47
	15	1,.25	1.34
Thick rye sourdough	control (without additives)	1.47	1.52
	5	1.38	1.42
	10	1.34	1.38
	15	0.90	0.92

During storage, the value of crumb crumbling tended to increase in all the bakery products. Compared to the products made without additives, all the samples made with the increased amount of the inulooligosaccharide syrup showed decreased crumb crumbling. The lowest dynamics of crumb crumbling was found in bakery products made by the sponge and dough method, and those made using thick rye sourdough, with 15% inulooligosaccharide syrup added.

The study yielded the optimal methods for making bakery products from wheat flour by the sponge and dough method and from a mixture of wheat and rye flour, using thick rye sourdough, with the addition of inulooligosaccharide syrup in the amount of 15% by flour weight.

The actual content of inulin was determined in bakery products made with inulooligosaccharide syrup added in the amount of 4.9 g per 100 g of product in bakery products made from wheat flour and that added in the amount of 5.3 g per 100 g of product in bakery products made from a mixture of wheat and rye flour.

According to GOST R 52349 'Food products. Functional food products. Terms and definitions', bakery products supplemented with inulooligosaccharide syrup are considered a functional food product, since 100 g of bakery products contain on average 50% of daily physiological need for inulin; therefore, these products can be referred to enriched bakery products in accordance with TR CU 021/2011 [11].

According to Appendix B (recommended) 'The list of types of Information allowed for use in relation to functional food ingredients contained in functional food products, justified from the evidence-based medical point of view' to GOST R 55577-2013 'Specialized and functional food products. Information about the distinctive features and effectiveness', these bakery products enhance normalization of the intestinal microflora.

Based on this comprehensive study, a draft technical documentation was developed for bakery products made from wheat flour and those made from a mixture of wheat and rye flour enriched with inulin.

4 Conclusions

The study results on the effect of inulooligosaccharide syrup from topinambur on organoleptic, physical and chemical indicators of quality and storage stability of bakery products showed that the studied syrup added in the amount of 5, 10, and 15% by flour weight did not significantly affect the porosity, moisture content and acidity of bakery products made by the straight dough, sponge and dough, and quick sponge methods and using thick rye sourdough. Bakery products made by different methods and supplemented with inulooligosaccharide syrup in the amount of 10 and 15% were characterized by a brighter crust and sweet flavor compared to the control and products made with 5% of the studied syrup. A 2–7-fold increase in the mass fraction of sugar was found for bakery products made by different methods compared to the control.

The lowest staleness rate and crumb crumbling were revealed in bakery products made from wheat flour by the sponge and dough method and supplemented with inulooligosaccharide syrup in the amount of 15%, and in bakery products made from a mixture of wheat and rye flour using thick rye sourdough. The study yielded the optimal methods for making bakery products from wheat flour and a mixture of wheat and rye flour (by the sponge and dough method and using thick rye sourdough), and the optimal amount of inulooligosaccharide syrup that attained 15% by flour weight. Consumption of 100 g of bakery products provides on average 50% of daily physiological need for inulin; therefore, these products can be referred to enriched bakery products in accordance with TR CU 021/2011. A systematic use of these food products enhance normalization of the intestinal microflora.

References

1. Kupin G.A. *Study of inulin hydrolysis in Jerusalem artichoke juice* / G.A. Kupin, O.E. Ruvinsky, G.M. Zaiko. Proceedings of universities. Food technology. 2002. No. 5–6. Pp. 78–79.
2. Nazarenko M.N. *Changes in inulin in Jerusalem artichoke tubers during storage* / M.N. Nazarenko, T.V. Barkhatova, M.A. Kozhukhova, I.A. Khripko, E.V. Burlakova // Polythematic network electronic scientific journal of Kuban State Agrarian University (Scientific journal of KubSAU) [Electronic resource]. Krasnodar: KubGAU, 2013. No. 10 (094). IDA: 0941310017. Access mode: http://ej.kubagro.ru/2013/10/pdf/17.pdf.
3. MR 2.3.1.1915-04 Recommended levels of consumption of food and biologically active substances. Moscow, 2004.
4. Perkovets M.V. *Inulin and oligofructose are common functional ingredients* // Oils and fats. 2008. No. 5. Pp. 2–4.
5. Koryachkina S.Ya. *Effect of the degree of polymerization of inulin and oligofructose molecules on their residual content in rye-wheat custard bread for functional purposes* / S.Ya. Koryachkina, D.K. Baibasheva. Proceedings of universities. Food technology. 2010. No. 1. Pp. 28–30.
6. K.N. Chizhova, T.I. Shkvarkina, N.V. Zapenina, I.N. Maslov, F.I. Zaglodin. *Technochemical control of bakery production* M.: Food industry, 1975. 480 p.
7. Guidance on methods of quality control and safety of biologically active food additives. M.: Federal Center for State Sanitary and Epidemiological Surveillance of the Ministry of Health of Russia, 2004. 240 p.
8. Recommended levels of consumption of food and biologically active substances: Guidelines. M.: Federal Center for State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia, 2004. 46 p.
9. Collection of technological instructions for production of bread and bakery products. M.: Preiskurantizdat, 1989. 497 p.
10. Guidance on organizing and conducting the technological process at bakery enterprises. M.: Food industry, 1999. 216 p.
11. Technical regulation of the Customs Union (TR CU 021/2011). ‘On food safety’ / Approved by the Decision of the Commission of the Customs Union as of December 9, 2011. No. 880. Electronic resource: www.tsouz.ru, 2011. 242 p.