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POTATO FIBRE PREPARATION – CHEMICAL CHARACTERISTICS, MICROSTRUCTURE AND FUNCTIONAL PROPERTIES IN BAKING PRODUCTS

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Key words: potato fibre preparation, wheat flour, dietary fibre, mineral compounds, functional properties, microstructure, bread crumb

Potato fibre preparation (PFP), as the by-product of industrial potato starch isolation, can be a potential functional additive in the food technology due to its sorption properties. The objective was to study industrial potato fibre preparation used as a supplement of wheat flour (15 g per 1 kg of wheat flour) to obtain the following thermally-stabilised complex: wheat starch–water–gluten proteins–mineral components. While determining the affinity of fibre to water, for the wheat flour or potato fibre preparation, the predominant amount of the insoluble fraction (IDF) of dietary fibre over the soluble fraction (SDF) was observed. Due to PFP sorption properties, the supplementation of wheat flour with this preparation enhanced the swelling capacity of starch granules in the dough and favoured gelling as well as mechanical and molecular behaviour of water in the bread structure. The microstructure proofs of bread crumbs indicated an indirect participation of potato fibre components in fibrous construction of gluten network formation. The complementation of soluble and insoluble fibre fractions and some elements, especially potassium, phosphorus, calcium, magnesium or microelements iron, zinc, copper, could be provided in baking products. The results indicate that this potato fibre preparation could be applied as dietary component in nutritional prophylaxis in everyday diet of adults and young people as well.

INTRODUCTION

Hipsley [1953] was one of the first who used the term "dietary fibre". It was used as an abbreviation for the non--digestible constituents that make up the plant cell wall in an attempt to distinguish some property or constituent of the food above and beyond what was then being measured by the crude fibre method. Since that time numerous definitions have been proposed. The new definition of dietary fibre [Jones, 2000], which was accepted in 2001 by the American Association of Cereal Chemists [Gray, 2003], is as follows: *"Dietary fibre is the edible parts of plants or analogous carbohydrates that are resistant to digestion and absorption in the human small intestine with complete or partial fermentation in large intestine"*. It emphasises, however, that: *"Dietary fibre includes polysaccharides, oligosaccharides, lignin, and associated plant substances. Dietary fibre promotes beneficial physiological effects including laxation, and/or blood cholesterol attenuation, and/or glucose attenuation"* [DeVries, 2003].

Dietary fibre, as a food product, is present in significant amount in cereal-based food such as bran and breakfast cereal flakes, and in raw fruits or vegetables such as: apples, carrot, citruses and soybean. It is known as a low energetic or high dietary fibre component of slimming diets.

Potatoes are known as a very good source of starch which can be used as a raw material for the production of many different products used in food industry, *e.g.* glucose or fructose syrups and maltodextrins [Kuntz, 1997] or for non-food uses, *e.g.* as pharmaceutical products or in paper production, as adhesives or thermoplastics [Leszczyński, 1999]. The crop of potato tuber in Poland in 2000 was about 24.2 mln tons, and 6% of them was used in industry (alcoholic, consuming products and starch industry) [Golachowski, 2002]. Potato tubers can be also a rich source of dietary fibre, which is a technological by-product obtained during industrial starch separation. In Sweden, potato fibre ("Potex") containing 80.4% d.m. of total fibre was obtained [Theander *et al*., 1995]. The potato fibre in food technology seems to be potentially atractive functional addititive product, *e.g.* for its unique absorption properties. It could be suggested as a substitutional product of gluten, caseinate, soy protein or milk powder. The potato dietary fibre could be a promising double-purpose component with good technological properties and a health promoting product consumed every day as baking products.

In the last decade, aging of European societies exceed the estimated threshold (15%) qualified as the index of eldery (above 60 years) people per cent in the whole population [Kowrygo & Kutermankiewicz, 2001]. The authors affirm that at present every fifth inhabitant of Northern Europe (20.1%) and every sixth of Eastern Europe (17.3%) has at least 60 years of age. In Poland in 2000, that index reached 16.7%, and it will be probably growing in next years. Therefore it is of crucial importance to pay attention to functional products, especially to the so-called "geriatric food" [Rutkowski, 2001].

The last quarter-century has brought changes into life and nutritional model, which resulted in an increased population of overweight people, also among children and young people. It is an important factor of a growing risk of such diseases as cardiovascular diseases, type 2 diabetes or diabetes incidence in children and young people. According to WHO,

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the diminution of fat, cholesterol, sugar (particular saccharose) and salt consumption is recommended coincidentally with enlargement of polysaccharides (starch) and dietary fibre consumption [FAO Report, 1998].

The research focused on determining the chemical, functional properties and microstructure of the potato fibre preparation as a new Polish by-product. The aim of the research was to assess the potato fibre preparation as a supplement of wheat flour for making the following complex formation: wheat starch-water-gluten proteins-potato fibre preparation-mineral compounds as well as its effect on retention of dietary fibre fractions and elements in thermally-stabilised structure.

MATERIALS AND METHODS

Material

The potato fibre preparation was obtained during industrial starch isolation from potato tubers in a Polish company. The dough was laboratory prepared from commercial wheat flour with the addition of 1.5% of potato fibre preparation (PFP) at the optimal amount of water (350 B.U. of consistency), 3% of *Saccharomyces cerevisiae* yeast and 1% of rock salt. The bread was obtained after 1-h fermentation of dough and baking in a laboratory oven at 225^{0}C (Sago S.A. co., Poland).

Methods

Chemical components were determined as follows: the starch content acc. to AOAC [1975]; the nitrogen by the Kjeldahl's method; the ash after mineralisation at 700°C [AOAC, 1990], crud fibre acc. to Polish Standard [PN-ISO 5498: 1996]. The content of dietary fibre fractions, soluble (SDF) and insoluble (IDF), was measured with the enzyme-gravimetrical method of Asp *et al*. [1983], using the following enzymes: Pepsin from porcine gastric mucosa, 2000 FIP-U/g, 107190, Merck; Pancreatin from porcine pancreas, 4xU.S.P., P-1750, Sigma; Termamyl 120L, Novozymes.

The contents of heavy metals, *e.g.* lead and cadmium, were determined by atomic spectrometry with electrothermal atomization acc. to Polish Standards [PN-EN ISO 11212-3: 2001] and [PN-EN ISO 11212-4: 2001], respectively. Sodium, potassium, calcium, magnesium, manganese, copper, iron and zinc contents were determined by flame atomisation method using Varian Atomic Absorption Spectrometer SpectrAA-20 acc. to apparatus producer recommendation. The analysed material was prepared by dry mineralisation in quartz crucible at a temperature of 450°C, solubilised with nitric acid (Polish analytical purity product) mixed with water (1:1) and diluted with 0.1 mole solution of nitric acid. The phosphorus content was determined by Marsh colorimetric method after wet mineralisation with mixture of nitric acid with water (1:0.4) and few drops of sulphuric acid [Marsh, 1959]. Molybdenic acid was used for colour reaction and the measurements were performed with VSH-2P apparatus at 310 nm.

The functional properties, such as water binding capacity (WBC) and oil sorption, were also analysed [Soral-Śmietana, 1993; Soral-Śmietana *et al*.,1998].

The wet samples for scanning electron microscopy (SEM) were prepared after immediate fixing acc. to Kalab [1981]. At the end, they were dried at the critical point in a Balzers Union drier acc. to Dziuba *et al*. [1994]. Dry samples were fixed to aluminium stubs and coated with gold in a JEE 400 vacuum evaporator. The images were analysed on a JSM 5200 microscope at 5-10 KeV.

RESULTS AND DISCUSSION

In this work, chemical components of wheat flour and potato fibre preparation (PFP) were characterised (Table 1). The major components of wheat flour were starch (78.1% d.m.) and protein complex constituting over 13% d.m. (Nx5.7). The analysed wheat flour was visualised as SEM-picture in Figure 1A, in which the starch granules of different size and shape are connected with proteins structures and cell wall fragments. The potato fibre preparation (PFP) contained crude fibre as a cellulose and lignin and dominating amounts of polysaccharides and/or degraded potato starch which can be hydrolysed to dextrins or glucose in acid environment. It was confirmed in the SEM-microstructure of the investigated PFP, where the potato starch granules were not observed (Figure 1B). The content of protein in PFP, 8.15% d.m., was calculated with the same coefficient as for wheat flour (Nx5.7).

TABLE 1. Proximate chemical composition of investigated materials (% d.m.).

Sample	Starch/ /Polysaccharides	Total protein (Nx5.7)	Ash	Crude fibre
Wheat flour	78.09±3.42	13.11±0.13	0.56±0.03	0.91±0.07
Potato fibre preparation (PFP)	42.37±2.25	8.15±0.08	2.73±0.23	18.7±0.17
Crumb:				
control	76.22±1.77	12.83±0.11	0.85±0.06	1.15±0.05
with 1.5% PFP	74.63± 0.93	13.11±0.10	0.95±0.06	1.76±0.09

In spite of the fact that dietary fibre, as a dietary component, does not belong to biologically-active substances, *i.e.* mineral components or vitamins, it plays many important physiological functions in every section of the gastrointestinal tract [Hasik & Bartnikowska, 1987]. In the first phase of digestion, it stimulates production of saliva and provokes chewing. In the stomach, it buffers and binds the excess of hydrochloric acid. In the small intestine, as a spongy mass, it fills its profile, causing blood supply and provokes peristaltic. It is also a substrate of desirable bacterial flora development and affects saccharides and fat metabolism in the large intestine. Two categories of dietary fibre, soluble and insoluble, are often determined analytically, depending on their affinity to water and buffer solutions. It is an important property of dietary fibre in food. In the experimental potato fibre preparation, the contents of two fibre fractions, IDF and SDF, were determined (Table 2) and their microstructures were presented in Figure 2A and 2B. The soluble dietary fibre

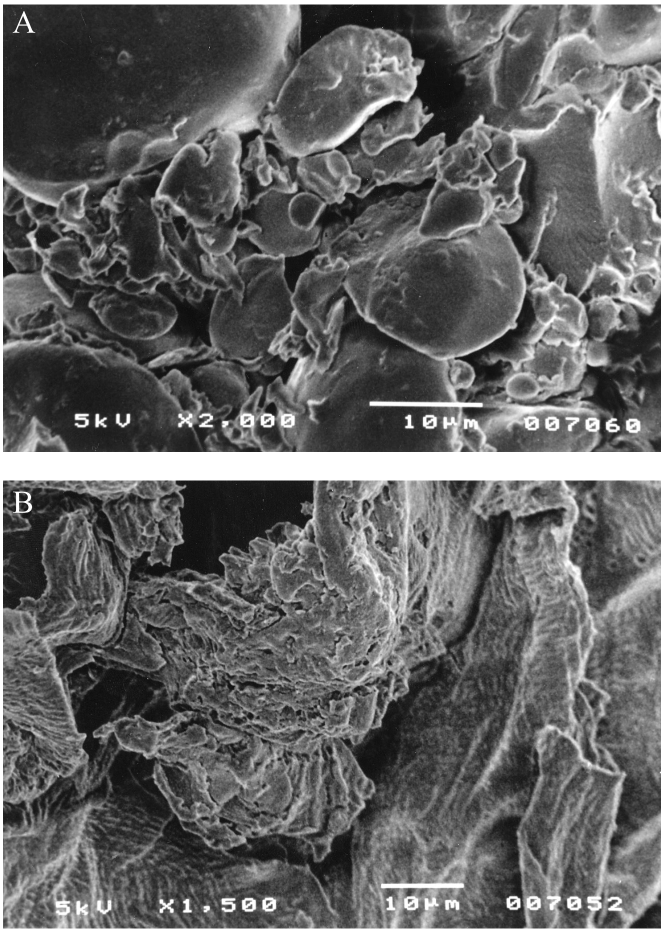

FIGURE 1. Microphotographs of: A – wheat flour; B – potato fibre preparation

fraction had generally dense structure (Figure 2A), quite different structure indicated insoluble fraction, which presented large of fragments with the smooth surface with some distance between and diverse spatial forms (Figure 2B). A comparison of wheat flour and the investigated PFP shows the significant differences in both analysed dietary fractions. However, the IDF included into the both basic materials was dominating (Table 2).

In food products, the soluble fibre polysaccharides (hemiceluloses or pectins) can be used as food additives – thickeners, stabilizers, emulsifiers and gelling agents. Many

TABLE 2. The content of insoluble (IDF) and soluble (SDF) fraction in investigated materials.

Sample	Dietary fibre fractions (%)	
	Insoluble (IDF)	Soluble (SDF)
Wheat flour	2.36±0.05	1.16±0.04
Potato fibre preparation (PFP)	38.58±1.06	4.12±0.6
Bread crumb:		
control	4.86±0.5	1.15±0.04
with 1.5% PFP	6.31±0.7	1.35±0.03

The content was determined in triplicate.

of SDF are quickly and extensively degraded and fermented in the large intestine, whereas insoluble fibre polysaccharides are more slowly and less completely degraded and fermented [Harris & Ferguson, 1999].

According to a recent dietary fibre definition [Jones, 2000; DeVries, 2003], DF is composed not only of polysaccharides such as cellulose, hemicelluloses, pectins and lignin, not belonging to polysaccharides, but also of *"oligosaccharides and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine, but are partly or completely fermented in the large intestine"*. The polysaccharide components of dietary fibre consist of linear and branch chains, and their general components are aldohexoses (D-glucose, D-galactose, D-mannose) and aldopentose (mainly L-arabinose and D-lactose) but also derivatives of saccharides oxidation – uronic acids (D-glucuronic acid and D-galacturonic acid) [Theander *et al*., 1995]. However, according to the quantitative enzymatic-gravimetrical methods, it is not possible to identify which components can occur as the so-called "analogous carbohydrates".

After the addition of 1.5% of the potato fibre prepartion (PFP) to wheat flour during technological process of dough kneading, some changes in the hydrophilic and hydrophobic properties were observed, but PFP showed special affinity to water (Table 3). Next technological processes – yeast fermentation and baking, caused an increase in the contents of each

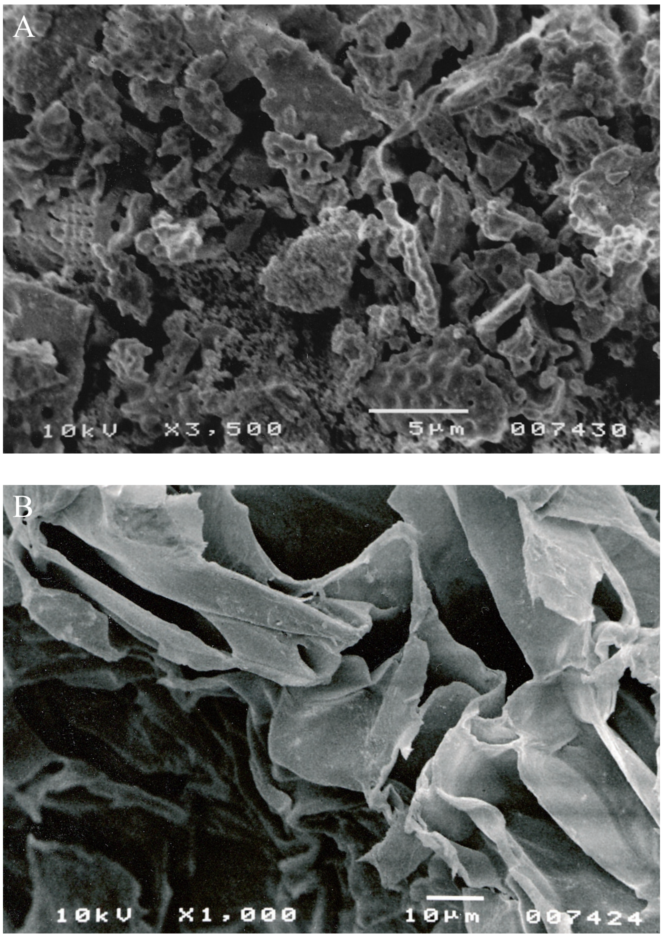

FIGURE 2. Microphotographs of dietary fibre fractions of the potato fibre preparation: A- soluble (SDF); B - insoluble (IDF).

of the analysed chemical component in the experimental baking product, compared to the control (Tables 1 and 2). The microstructure (SEM) of the experimental bread crumb showed that added fibre components participated indirectly in fibrous construction of gluten network formation (Figures 3A, 3B). Due to sorption properties (Table 3), the supplement addition enhanced starch granules swelling capacity in the dough and favoured gelling as well as mechanical and molecular behaviour of water in the bread crumb structure. Certain differences were presented on microphotographs as well as thermally-stabilised two phases containing gluten network with – as dispersed phase – diverse deformed starch granules during its swelling/gelatinise (Figure 3B). Taking into account both food structure and physiological functions, the most important physico-chemical dietary fibre properties appear to be: ionic charge, degree of hydratation or water-holding capacity, adsorption capacity, viscosity.

Because of diet supplementation with biologically active components, it is interesting and important to analyse the retention of mineral components. The additional source of elements in the experimental product was 15 g supplementation of potato fibre preparation per 1 kg of wheat flour. The use of PFP during technological process treatment evoked an increase in the contents of macro- and microelements (Table 4). These results indicate that supplementation of 15 g PFP resulted in increased contents of K, P and Na (164-190 mg/kg of bread crumb) and

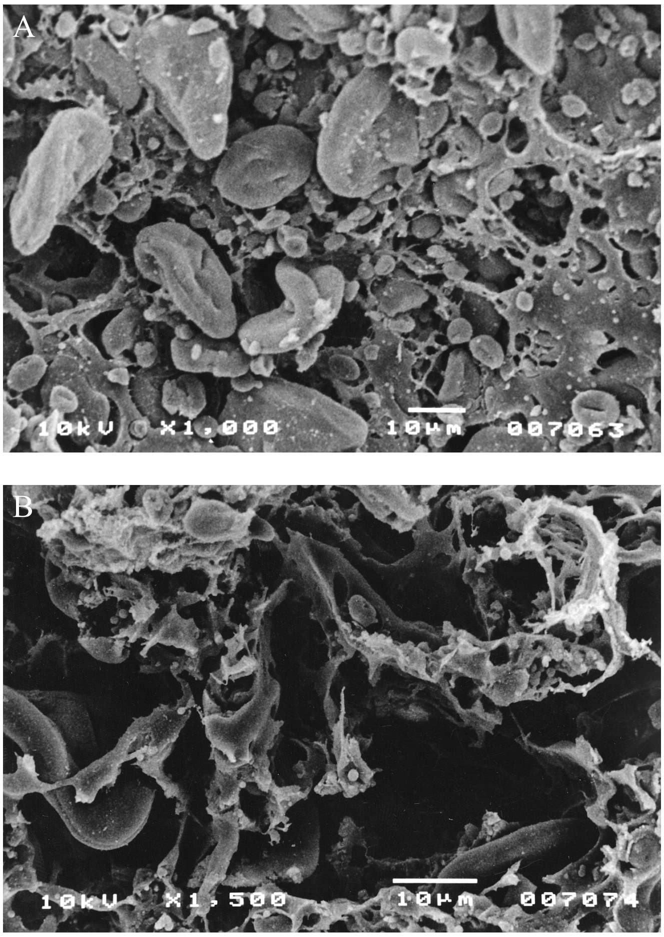

FIGURE 3. Microphotographs of bread crumb: A – control; B – with 1.5% of PFP.

TABLE 3. Water binding capacity and oil sorption of investigated materials.

Sample	Water binding capacity (g water/1 g d.m. of sample)	Oil sorption (g oil/1 g d.m. of sample)
Wheat flour	0.84 ±0.07	1.64 ±0.12
Potato fibre preparation (PFP)	5.20 ±0.31	3.53 ±0.11
Wheat flour with 1.5% PFP	0.97 ±0.08	1.86 ±0.09

The results was determined in triplicate.

TABLE 4. Content of macro-, microelements and toxic elements (mg/kg) in the investigated materials.

Mineral compounds	Wheat flour	PFP	Bread crumb (control)	Bread crumb (with 1.5% PFP)
P	1078.0	1409.0	1169.0	1264.0
Na	86.0	683.0	3600.0	3790.0
K	782.0	2142.0	1254.0	1418.0
Ca	172.0	24750.0	304.0	389.0
Mg	181.4	981.0	247.7	292.3
Mn	2.9	9.0	3.5	4.6
Cu	1.7	2.9	1.2	2.0
Fe	8.2	473.5	9.9	24.3
Zn	3.9	54.6	7.2	9.4
Pb	0.01	0.12	< 0.01	< 0.01
Cd	trace	0.02	< 0.01	< 0.01

Analysis were duplicated

contents of Ca and Mg (85 and 45 mg/kg, respectively). The interaction and/or binding of microelements in experimental bread crumb could be ordered in growing contents: $Cu<Mn<Zn<Fe$. However, it was confirmed that the content of toxic elements (cadmium and lead) was not harmful taking into account the food safety. The interaction and/or binding with biopolymers, starch and proteins, is possible through the special functional groups of different components of dietary fibre. It should be emphasised [Amado, 1994] that the functional groups of dietary fibre, such as: (1) carboxylic acid groups: pectic substances, hemicelluloses, protein side chains; (2) hydroxyl groups: cation binding by non-ionic complex; (3) inorganic acid groups: *e.g.* phosphoric acid groups in phytic acid; (4) lignin interactions: non-ionic involved in ion exchange will influence the interaction and/or binding of elements.

The prognoses for the Polish society show that by the year 2030 both stabilization and diminishing of birth rate will cause an increase in the elderly population number. In the next decades, the expected numbers could rich 19.0% in 2010; 24.4% in 2020 and 26.7% in 2030 [Kowrygo & Kutermankiewicz, 2001]. Therefore attempts should be made to fulfill the demand for the functional food products [Soral-Śmietana *et al.*, 2001]. The results of this work suggest that the potato fibre preparations could be applied as a good functional and dietetic additive either in the food technology or as a better shelf-life dietary baking product [Walkowski *et al*., 2002], or as a nutritional prophylaxis agent in everyday diet.

CONCLUSIONS

The potato fibre preparation used in this experiment could be a good supplement of food providing increased contents of dietary fibre and elements. In baking products, the application of 15 g of PFP per 1 kg of wheat flour as basic materials, changes the hydrophilic properties of mixing dough and improves the swelling capacity of starch granules and/or favours gelling as well as mechanical and molecular behaviour of water in the bread crumb structure. The supplementation of wheat flour with the insoluble and soluble fibre fractions and elements, especially potassium, phosphorus, calcium, magnesium or microelements as well as iron, zinc, copper, made an integral component of complex: wheat starch–water–gluten complex–potato fibre–mineral compounds, which can be applied in nutritional prophylaxis in everyday diet.

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