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BIOTECHNOLOGICAL APPROACHES FOR THE PRODUCTION OF FUNCTIONAL FOODS AND SUPPLEMENTS FROM CEREAL RAW MATERIALS

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Анотація: Побічні продукти переробки зерна такі як висівки, мучки, зародки, відповідають вимогам функціональних продуктів харчування значно більше, ніж борошно. Нові біотехнологічні підходи запропоновані для переробки вторинних зернових продуктів в харчові продукти і інгредієнти, такі як збагачені добавки харчових волокон, β-глюкани, ферментовані зернові продукти, зернові біопродукти, стійкі крохмалі, пребіотики, модифіковані геміцелюлози, білкові збагачувачі.

Ключові слова: вторинні зернові продукти, ферментативна обробка, функціональні продукти і дієтичні добавки.

Аннотация. Побочные продукты переработки зерна, такие как отруби, мучка, зародыш, соответствуют требованиям функциональных продуктов питания значительно больше, чем мука. Новые биотехнологические подходы, предложенные для переработки вторичных продуктов в пищевые продукты и ингредиенты, такие как обогащённые добавки и функциональные продукты: концентраты пищевых волокон, β-глюканы, ферментированные зерновые продукты, зерновые биопродукты, устойчивые крахмалы, пребиотики, модифицированные гемицеллюлозы, белковые обогатители.

Ключевые слова: вторичные зерновые продукты, ферментативная обработка, функциональные продукты и диетические добавки.

Introduction

Cereals are important sources of energy, carbohydrates, proteins, lipids and biological active components in the human diet. They can be considered as functional foods even without enriching. The expected annual growth rate of the functional food market ranged from 15 % to 20 % at the end of 2010 s to a possible 10 % more recently.

Perceived healthiness may be influenced by the type of cereals and the processing method used. In terms of functional food argue that perceived healthiness many be related to the enrichment processing methods used, health claims made and base products used in the process. This suggests that the methods of production is an important factor in the acceptability and consumption of functional foods.

Problem statement

Traditional processing technologies were developed largely in Ukraine considering sensory qualities of foods without focusing on their physiological functionality.

The aim of this work was application of biotechnological enzymatic methods for reprocessing of grain raw materials and by-products in food and biologically active supplements, as well as enriching agents and functional products.

Over the last 3 years Ukrainian production of all cereal grains has average about 50 mil. tons. Wheat is the leading grain in Ukraine representing almost 2/3 all cereal production.

Flour milling process causes redistribution or concentration of physiologically active ingredients of phytochemicals in the milling products due to the fact that phytochemicals and dietary fibers in cereal kernels are not uniformly distributed. Thus a significant amount of this compounds present in the bran. The results demonstrate that bran was 20 times more in dietary fibers (2, 3 and 48.6 g/100 g), 15 times higher in total phenolic compounds (180 μmol/100 g and 2700 μmol/100 g), 10 times higher in flavonoids (78 μmol/100 g and 810 μmol/100 g) than wheat flour.

So, by-products of grain processing such as bran, farine, and germ flakes correspond to requirement of functionality to much higher degree that the pare product – flour.

Literature review

Recent research studies add strong evidence that whole grain intake is protective against many diseases [1-4]. Whole grain has high concentrations of dietary fibers, resistant starch, and oligosaccharides but also they are rich in nutrients and phytochemicals with known health benefits. The wide range of protective components in whole grains and potential mechanisms for protection have been recently described [5].

The bran and germ fractions derived from conventional milling provide a majority of the biologically active compounds found in grain. Specific nutrients include high concentrations of B vitamins (thiamin, niacin, riboflavin, and pantothenic acid) and minerals (Ca, Mg, K, P, Na and Fe), elevated levels of basic amino acids (for example, arginine and lysine), and elevated tocol levels in the lipids, which have been linked to disease prevention.

Cereals are an important agricultural commodity and popular food ingredient worldwide. Cereals dietary fibers and other beneficial phytochemicals are concentrated in the bran fractions of wheat grain and others cereals. Bran is mostly used for low-value animal feed instead of human food ingredient [6].

Research promoting the production and consumption of cereal-based food ingredients and food products rich in natural products may provide new value-adding opportunities for cereal bran, whole cereal flour and other cereal-based food ingredients, which may benefit cereal growers, grain, processing industry, ingredient industry, and food manufactures. The consumer desire of health beneficial foods also promotes research in the fields of cereal biotechnological modifications of by-products of milling process [7, 8].

The present work refers to a method for treating cereals brans, specifically enzymatic treatment of cereals for the production of dietary fibers and starch modified products. By such method new improved modified starch products [9, 10].

Cereals can serve as a substrate to several types of enzymes. Consequently, use of enzymes or microorganisms during the manufacturing process of modified cereal products has been known for quite some time [11].

Fritze et al. [9] report a process to saccharify the starch contained in the cereal to from dextrose by enzymatic degradation using a, probably thermostable, α-amylase. The final product is claimed to have a good flavor and the dextrose produced [12].

In work [13] reported the use of glucoamylase in combination with glucose isomerase and optional α-amylase in the method for making cereal products naturally sweetened with fructose.

Cereal-based probiotic products have health-benefiting microbes and potentially prebiotic fibers. The development of new functional foods which combine the beneficial effects of cereals and health promoting bacteria is a challenging issue. Cereals are the good substates for the growth of probiotic strains and due to the presence of non-digestible components of the cereal matrix may also serve as prebiotics [14]. Due to complexify of the cereals, a systematic approach is required to identify the factors that enhance the growth of probiotic in cereals [15]. More studies are being done to demonstrate that cereals are suitable substrates for the growth of different *Bifidobacterium spp.* in a malt hydrolysate [16].

They are reported that many cereals supported the growth of probiotics with some differences.

Wheat and barley extracts were found to exhibit a significant protective effect on the viability of *L. plantarum*, *L. acidophilus* and *L. reuteri* under acidic conditions (pH 2.5) [17].

Main part

The classification of functional physiologically active ingredients of cereals and their effects are shown in two gropes: nondigestible carbohydrates or dietary fiber components (cellulose, hemicellulose, gums, pectin, β-glucans, oligosaccharides, resistant starch, etc.) and bioactive components (vitamins, minerals, phytochemicals – lignans, sterols, alkylresorcinols, carotenoids, tocopherols, phenolic acids, etc.).

As was noted above significant amount of biologically active compounds (BAC) presented in the bran of cereals. Therefore bran of cereals may be used as natural source of BAC and as raw materials for production of novel physiological functional ingredients and products.

Research on application of enzymes has been carried out for producing of novel functional cereal bioproducts and ingredients (fig. 1).

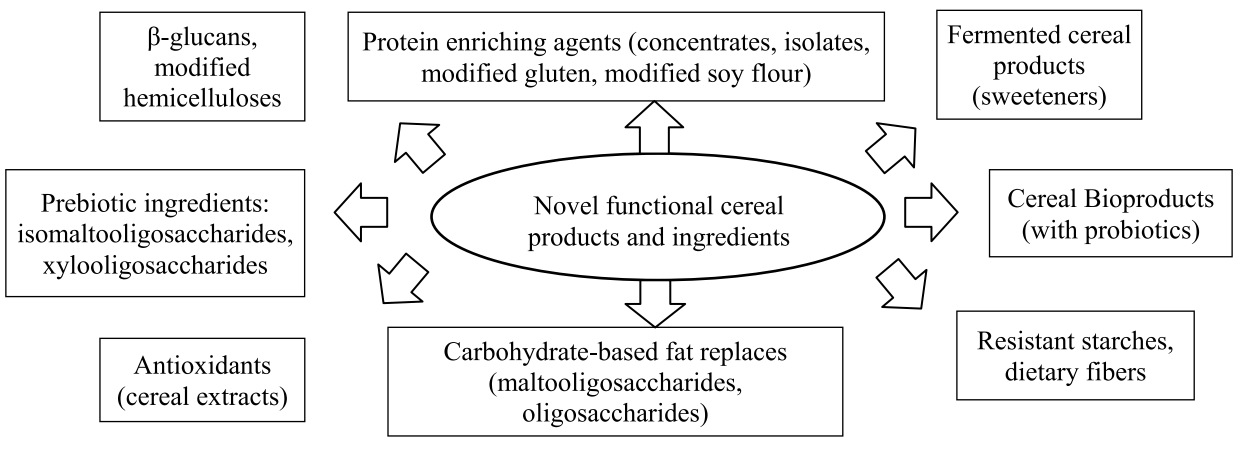

Fig. 1. Novel functional cereal products and ingredients

The developed biotechnologies are based on adding of exogenous and endogenous enzymes of grain and by-products as well as on activation of the endogenous enzymes of raw material. There were used the next enzymes: amylases, cellulases, hemicellulases, proteases, lipases and microorganisms, *Lactobacillus* and *Bifidus* (fig. 2).

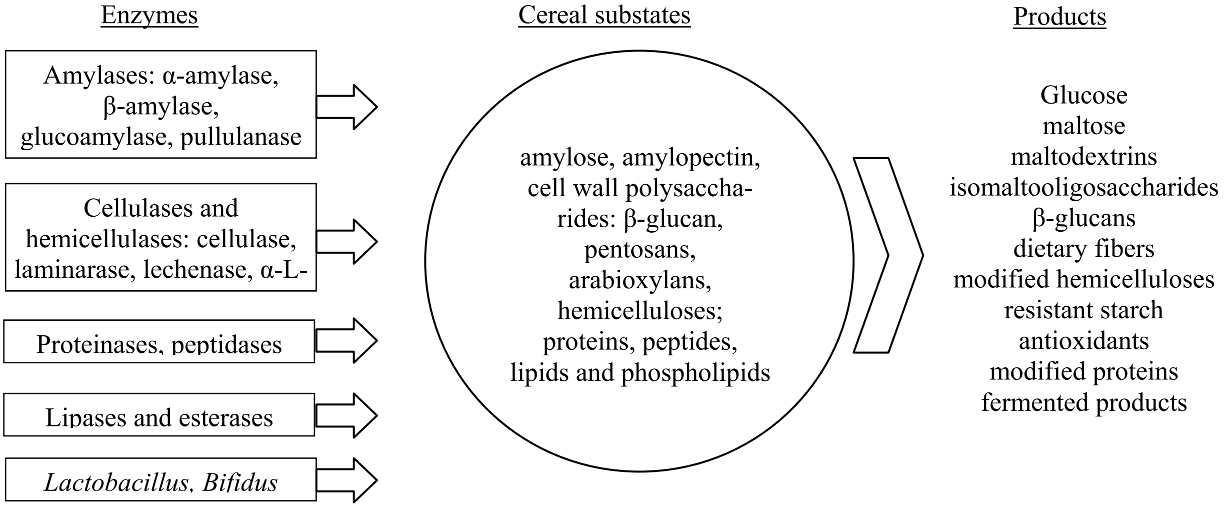

Fig. 2. Main enzymes and microorganisms used for production of cereal additives and products

The importance of dietary fibers (DF) in the human diet has been recognized since epidemiological and human studies. Current DF intake in Ukraine is a follows: men – 17.5 g/day and women – 15.8 g/day. The Health Association recommends 25 – 30 g/day.

In this part of investigations were working out of technologies of production of isolates and concentrates of DF from wheat bran. The chemical composition of different cereal bran has been shown the high concentrations of DF consisting of cellulose, hemicellulose, pectins and lignin. Isolates with high content of DF from wheat bran by enzymatic hydrolyse of starch polysaccharides. The varies possibilities for modifying of starch in the bran enzymatically are outlined in fig. 3.

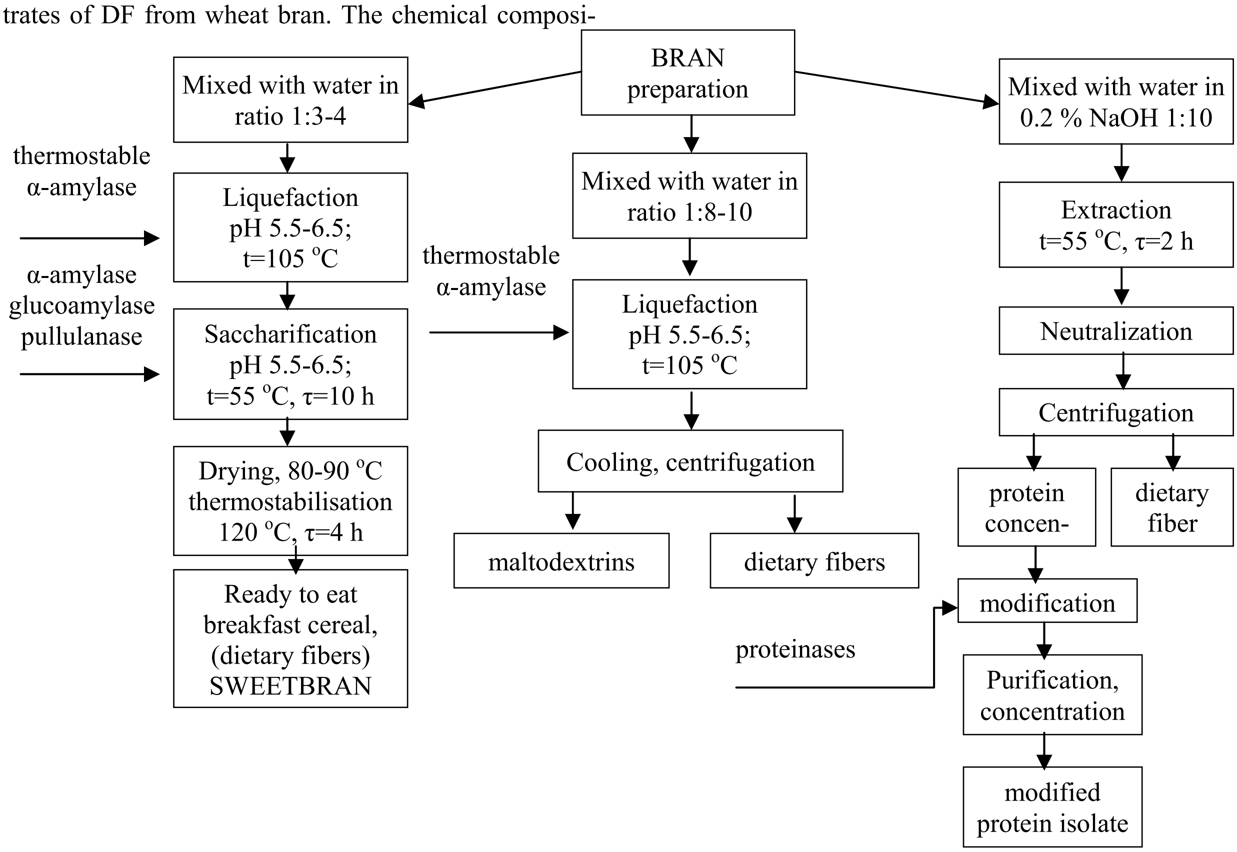

Fig. 3. Processes for making DF, modified protein isolate and maltodextrins

The first option of proposed technology is a preparation of ready-to-eat breakfast cereal product SWEETBRAN by conversion of starch of bran to glucose by liquefaction with thermostable α-amylase and saccharification by glucoamylase (hydration ration bran in water is 1 to 4).

The efficiently of the process of saccharification was improved by adding enzyme pullulanase to glucoamylase. The highest level of starch conversion (more than 94 %) was achieved by using combination of three enzymes: glucoamylase, pullulanase and α-amylase. For obtaining DF isolate was working out bioprocess that include liquefaction of gelatinized starch by α-amylase (hydration ration 1 to 8). After this treatment the dextrose equivalent of liquefied starch was 10 – 12 %. Soluble carbohydrates were purified by centrifugation, filtration and drying.

The table 1 shows the yield, content of DF preparations.

Table 1 – Yield content of DF hydration characteristics of some dietary fibers

Source of fibers	Treatment	Yield, %	Particle size (μm)	Swelling (mg/l)	Water retention (g water/g dry pellet)	Water absorption (ml water/ g dry fiber)	Dietary fibers, %
Wheat bran	α-amylase glucoamylase pullulanase	92-94	190-280	15-17	6.5-7.0	4.4-4.9	54-57
Wheat bran	thermostable α-amylase	64-66	200-290	16-19	8.5-9.3	5.1-5.5	70-78
Wheat bran	alkaline extraction	40-47	210-310	17-20	9-11	6.1-6.5	60-64
Rye bran	thermostable α-amylase	70-74	180-250	13-15	8-9	5.1-5.4	74-77
Barley bran	α-amylase	40-47	120-140	18-22	11-15	8-9	40-43

A food can be made functional with the addition of a health promoting entity, reducing or removing the concentrations of harmful components and modifying the nature of one or more components. Previously, a functional food was based on fortification with vitamins and minerals but recently, the concept moved towards food ingredients such as probiotics and prebiotics, which exert a positive effect on the gut microflora [4].

In previous investigations has been shown that cereal hydrolysates are good substrates for proliferation of probiotic microorganisms. The fermentability of different enzymatic hydrolysates of cereal bran were monitored during the growth of lactobacillus. Experiments revealed that all cereal hydrolysates can support the growth of lactobacillus to concentrations above 10^9 CFU/ml. It has been found that biopolymer complex of barley – DF and β-glucan, has stimulating effect as prebiotic on reproductive property of cells to $3.5\cdot10^9$ CFU/ml for *Lactobacillus* and $2\cdot10^9$ CFU/ml for *Bifidobacterium*.

A new process for making a function cereal bioproduct from barely has been developed (fig. 4).

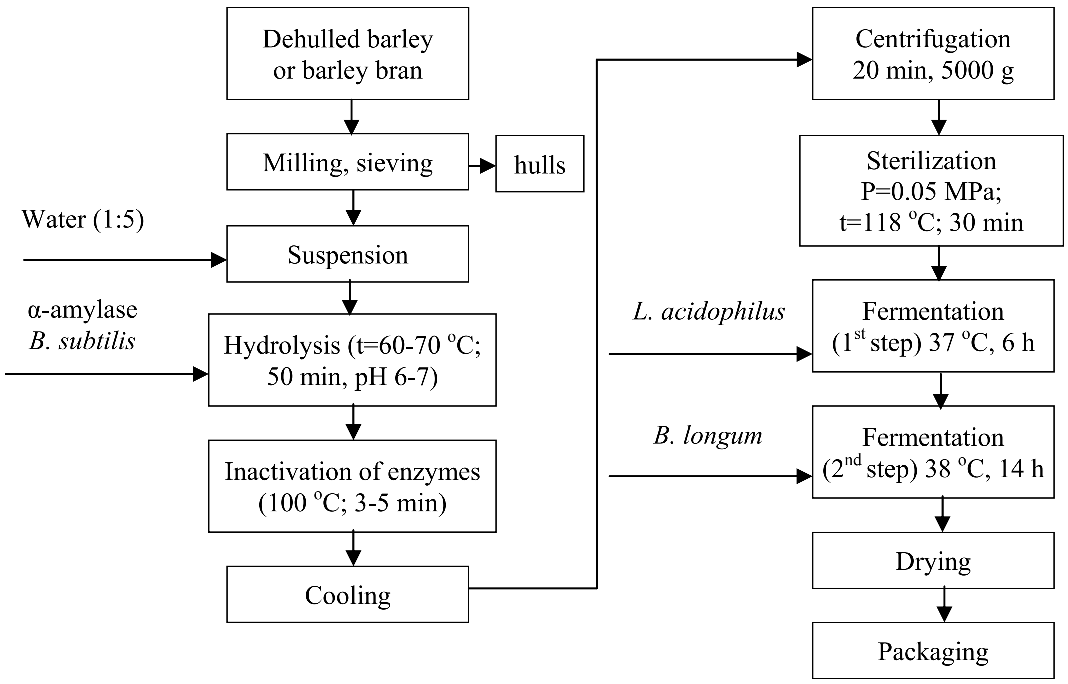

Fig. 4. Process for making a functional cereal bioproduct from barely

This process include a few steps: preparing of barley suspension and enzymatic hydrolysis of starch by α-amylase with consequent fermentation. Initially *Bifidobacterium* were cultivated during 6 h, and then *Lactobacillus* were inoculated and cultivation for another 14 h.

In the table 2 are demonstrated characteristics of some cereal bioproducts produced from bran of barley, oat, buckwheat, and soy flour.

Table 2 – Characteristics of some cereal bioproducts

Product types and cereal material used for the production	Proteins, %	Carbohydrates, g/100 g		Probiotic cultures
		digestible	dietary fibers	
“Bilamin” (bran or flour barley)	17±2	31.7	29.3	*L. acidophilus* *B. adolescentis*
“Avena” (oat bran or flour)	19±1	31.3	27.7	*L. acidophilus* *B. longum*
“Tonus” (flour of buckwheat)	15±1	44.3	23.8	*L. acidophilus* *B. adolescentis* *L. casei*
“Multisyrup” (25 % of flour barley, 25 % soy flour, 25 % buckwheat flour)	24±2	27.3	21.4	*L. acidophilus* *L. thermophilus* *L. bulgaricus*
“Trisan” (wheat bran)	15.2±1	24.6	33.5	*L. acidophilus* *B. longum*

Conclusion

By application of developed technologies we were able to obtain a wide range of new functional foods and dietary supplements from cereal by-products: isolated dietary fibers, β-glucans, fermented cereal products, cereal bioproducts with probiotic activity.

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