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Biotransformation of cereal raw materials in functional foods and supplements

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MOTIVATION

Cereals are important sources of energy, carbohydrate, proteins and biological active components in the human diet. They can be considered as functional foods even without enriching. However, 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

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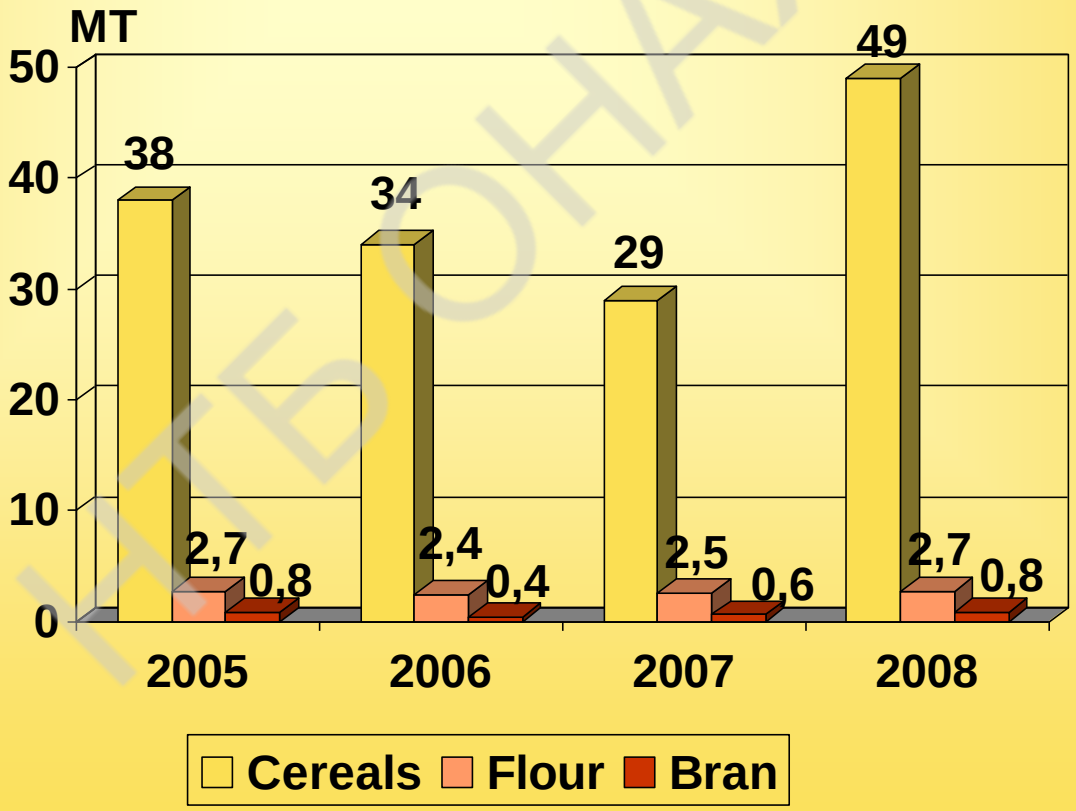
Production of cereals in Ukraine during the last years



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Dietary fibers and phytochemicals of milling fractions of soft wheat of Ukraine

Phytochemicals and Dietary Fibers	Flour	Bran
Dietary fibers, g/100g	2,3	48,6
Total phenolics, μmol/100g	180	2700
Flavonoids, μmol/100g	78	810
Total carotenoids, μmol/100g	64	210
Thiamin (B1), mg/kg	3,7	7,1
Riboflavin (B2), mg/kg	0,9	3,9
Niacin (B3), mg/kg	64	311
Pantothenic acid, mg/kg	5,4	30
Pyridoxine (B6), mg/kg	3,1	11,8
Folate (B9), mg/kg	0,4	2,1
Biotin (H), mg/kg	0,1	0,32
Total lignans, μg/g	0,8	35

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Functional physiologically active ingredients of cereals and their by-products

Nondigestible carbohydrates (dietary fiber components)

- **cellulose, hemicellulose, gums, pectin, β-glucan**
- **oligosaccharides, inulin**
- **resistant starch**

Micronutrients and main bioactive components

- **vitamins (folate, tocols, choline etc)**
- **minerals (P, K, Mg, Ca, Zn, Fe, Mn)**
- **phytochemicals (lignans, sterols, alkylresorcinils, etc)**
- **antioxidants (carotenoids, tocopherols, lignans, phenolic acid)**

HELTH BENEFICIAL EFFECTS

- **Reduced risk for some of cardiovascular diseases (hypertention, stroke, coronaryheart disease)**
- **Low body mass index and correction insulin level**
- **Low risk of type 2 diabets**
- **Redused danger of cancer and mortality**
- **Possible influence on colonic health and bacteria translocation**

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β-glucans, modified hemicelluloses

Protein enriching agents (concentrats, isolates, modified gluten, modified soy flour)

Fermented cereal products (sweeteners)

Prebiotic ingredients: isomaltooligo-saccharides, xylooligosaccharides

Novel functional cereal products and ingredients

Cereal Bioproducts (with probiotics)

Antioxidants (cereal extracts)

Carbohydrate-based fat replaces (maltooligosaccharides, oligosaccharides)

Resistant starches, dietary fibers

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Main enzymes and microorganisms used for production of cereal additives and products

Enzymes	Cereal substates	Products
Amylases: α-amylases, β-amylase, glucoamylase, pullulanase	amylose, amylopectin, cell wall polisaccharides: β-glucan, pentosans, arabinoxylans, hemicelluloses; proteins, peptides, lipides and phospholipides	Glucose maltose maltodextrins isomaltooligosaccharides β-glucans dietary fibers modified hemicelluloses resistant starch antioxidants modified proteins fermented products
Cellulases and hemicellulases: cellulase, laminarase, lechinase, α-L-arabinase		
Proteinases, peptidases		
Lipases and esterases		
Lactobacillus, Bifidus		

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Extraction of dietary fibers using biotechnological enzymatic methods

Composition of various bran from cereals of Ukraine (% of dry matter)

Sample	Dietary fibers	Constituents of dietary fibers				Starch	Protein	Lipids	Ash
		Hemice lluloses	cellulose	pectin	lignin				
Wheat	49,8	26,3	8,8	5,3	9,4	26,4	16,4	3,3	4,1
Rye	57,7	25,1	14,3	8,0	10,3	16,0	17,9	3,1	5,3
Triticale	46,3	17,8	12,6	5,1	10,8	25,4	18,3	2,9	5,0
Oats	15,1	8,7	3,7	0,5	2,2	59,2	14,0	7,0	2,2
Barley	30,5	18,3	7,8	0,7	3,9	38,4	17,4	8,6	4,3
Corn	56,0	32,3	14,7	0,3	8,7	24,7	9,3	7,3	2,7

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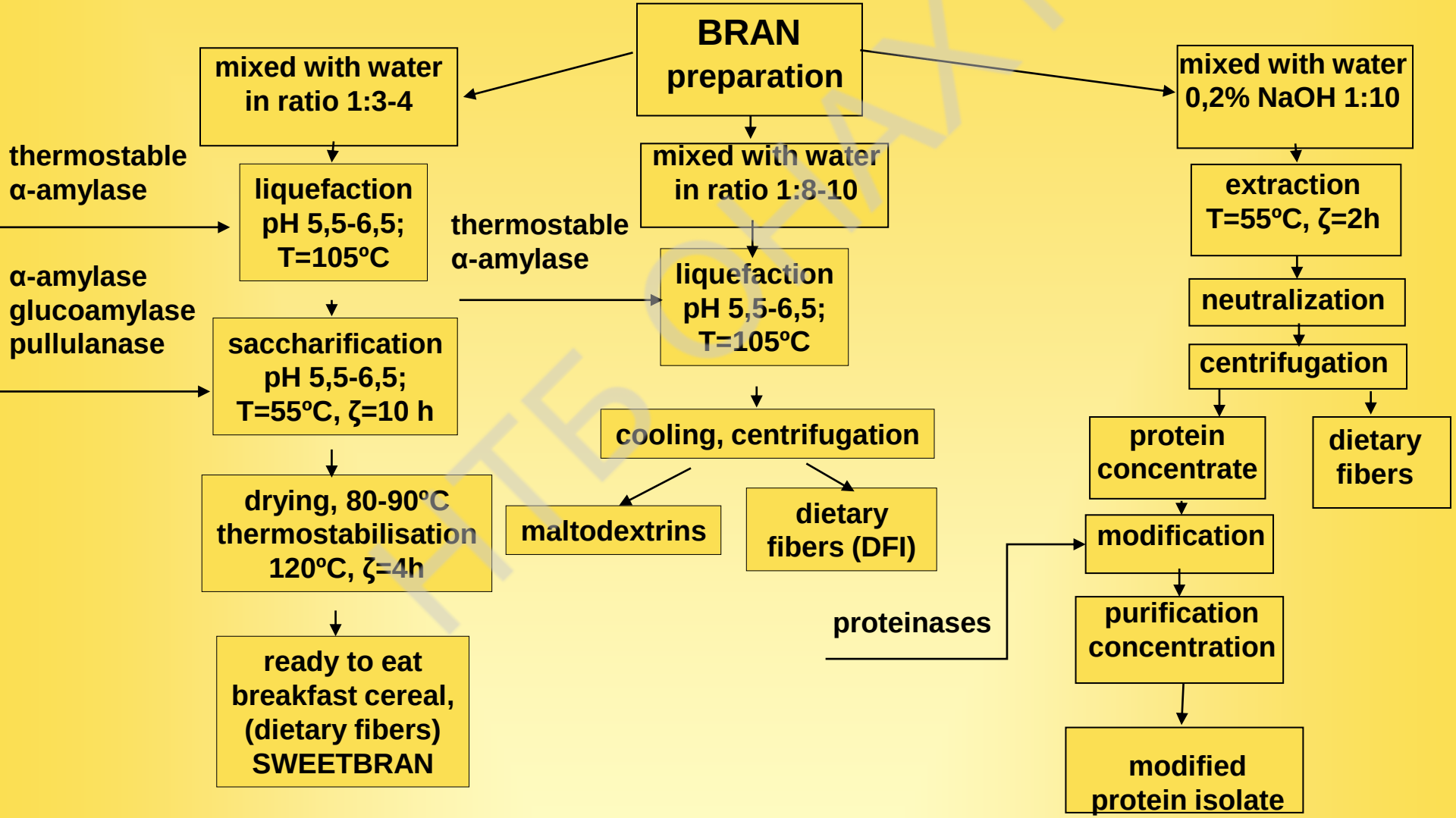

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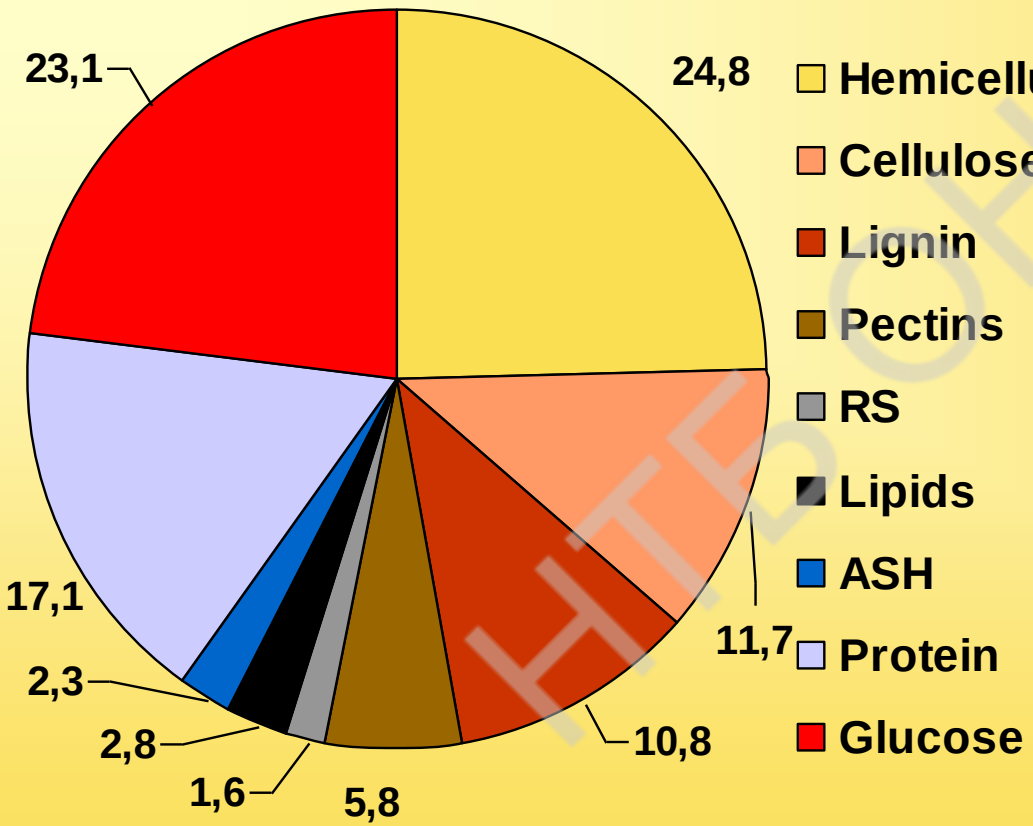
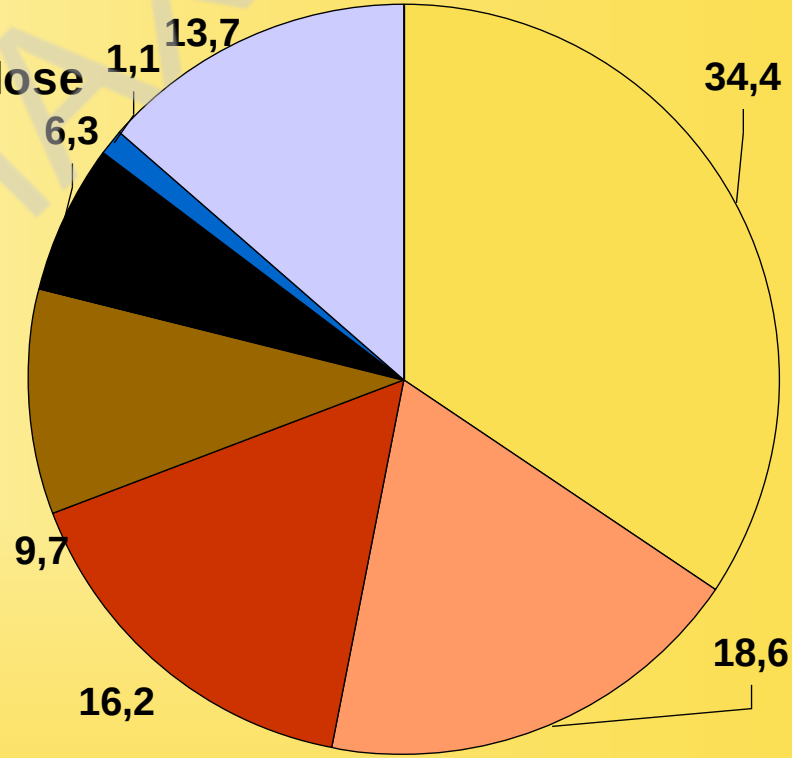
Chemical composition of dietary wheat fiber isolates



SWEETBRAN 53,1% dietary fibers



DFI 78,9% dietary fibers

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Yield, content of DF and hydration characteristics of some dietary fiber

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 glucoamy-lase 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

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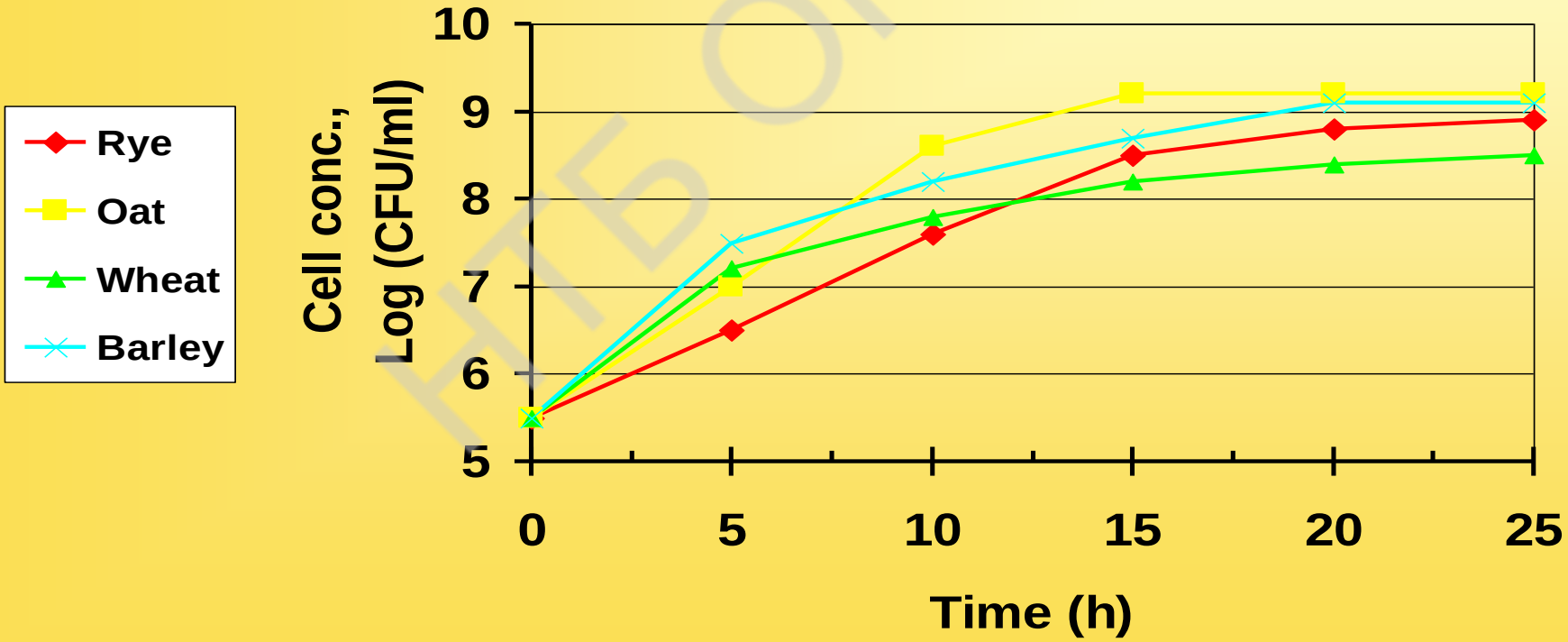
Fermentation of hydrolysates of cereal bran by Lactic Acid Bacteria

Evolution of cell concentration during grown of LAB in different hydrolysates of cereals



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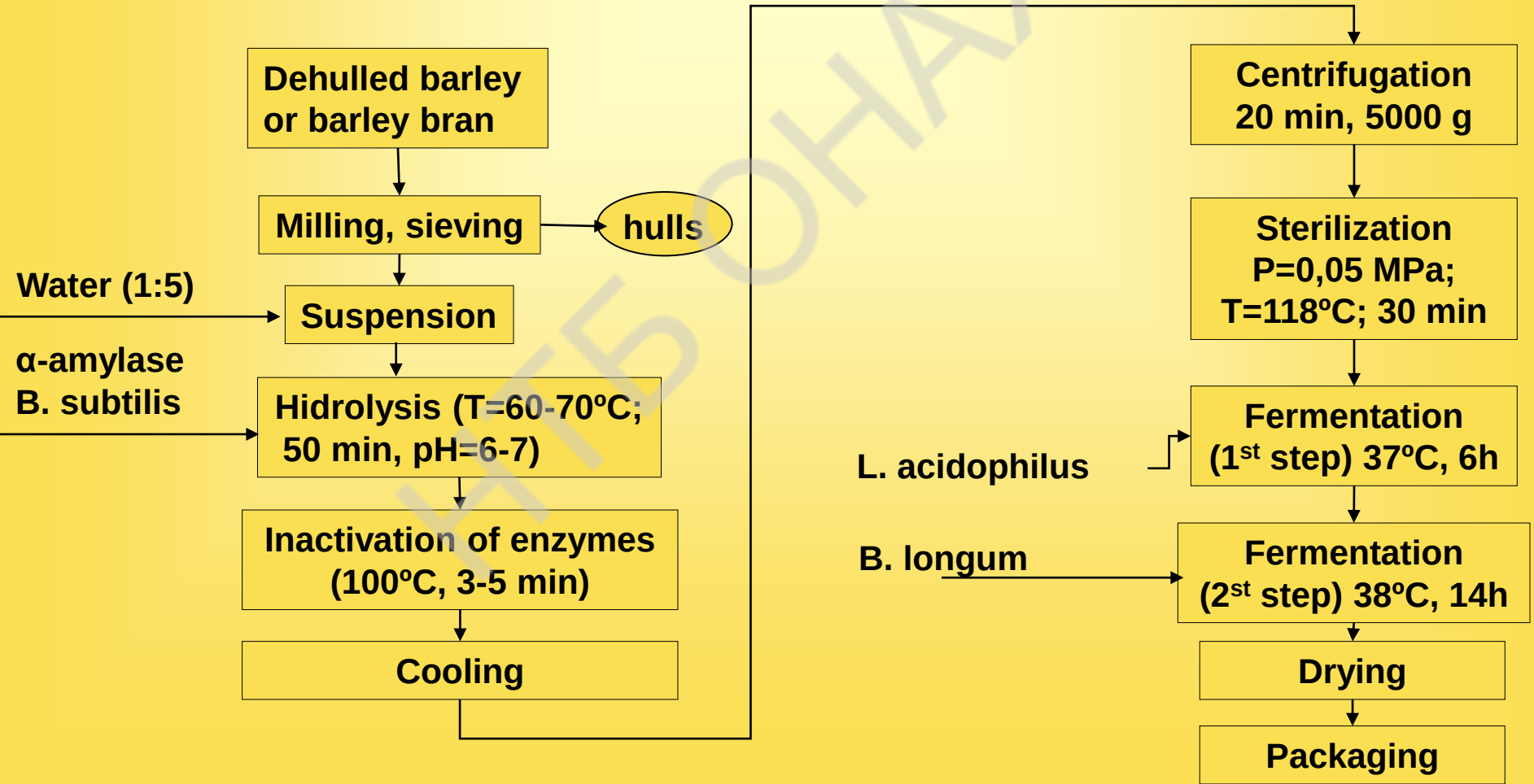
Process for making a functional cereal bioproduct "BILAMIN" from barley



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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 of barley)	17 ± 2	31,7	29,3	L. acidophilus B. adolesentis
"Avena" (oat bran or flour)	19 ± 1	31,3	27,7	L. acidophilus B. longum
"Tonus" (flour of backwheat)	15 ± 1	44,3	23,8	L. acidophilus B. adolesentis L. casei
"Multisyrup" (25% of flour barley, 25% soy flour, 25% backwheat flour)	24 ± 2	27,3	21,4	L. acidophilus L.termophilus L. bulgaricus
"Trisan"(wheat bran)	15,2 ± 1	24,6	33,5	L. acidophilus B. longum

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Structural modification of cereal starch by enzymatic methods

Characterization of starch isolates (% DM)

Cereal bran	Starch	RS	Amylose	MW 10^5	Temperature, °C	
					initial	final
Wheat	97,9	2,7	25	4,8	56	66,5
Rye	98,5	2,1	22	3,3	53,8	62,5
Triticale	98,6	1,9	23	4,4	55	63
Barley	97,6	2,9	28	0,44	62	67
Oat	98,3	3,3	24	0,31	68,4	74,7

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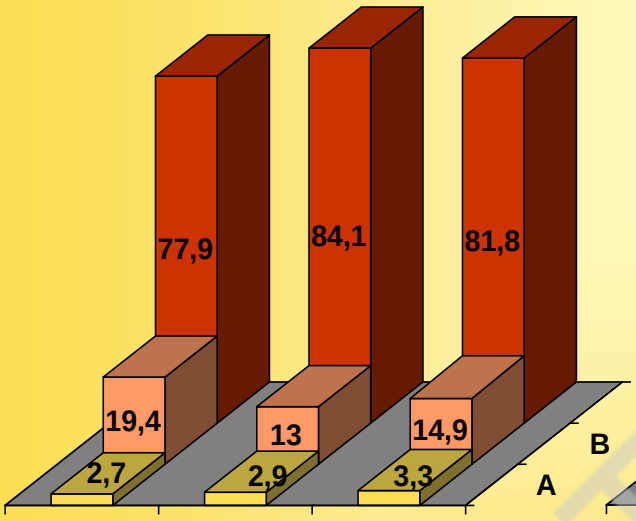
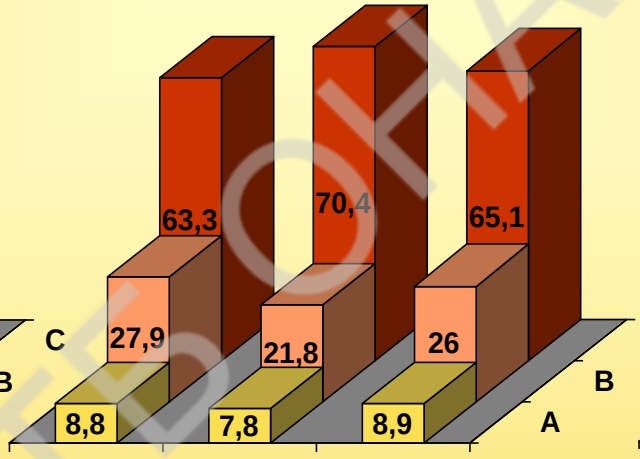
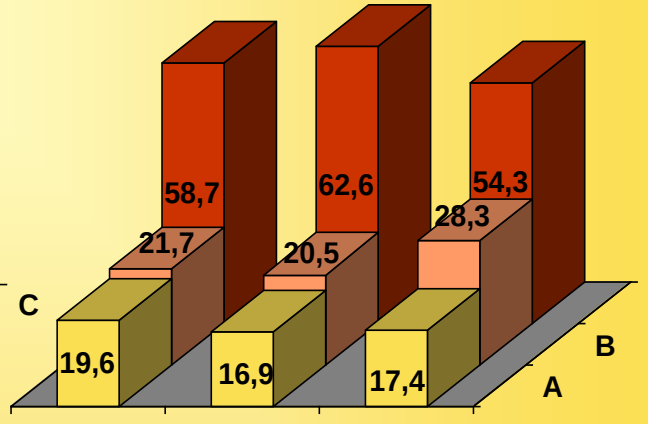
Contents of starch and enzyme-treated samples (%DS)



normal starch



β-amylase treated starch



α-amylase treated starch

A – resistant starch

B – slowly digested starch

C – rapidly digested starch

concentration of starch	10-15% of DS
concentration of enzyme	1-1,5% of DS
incubation time	3-7 h

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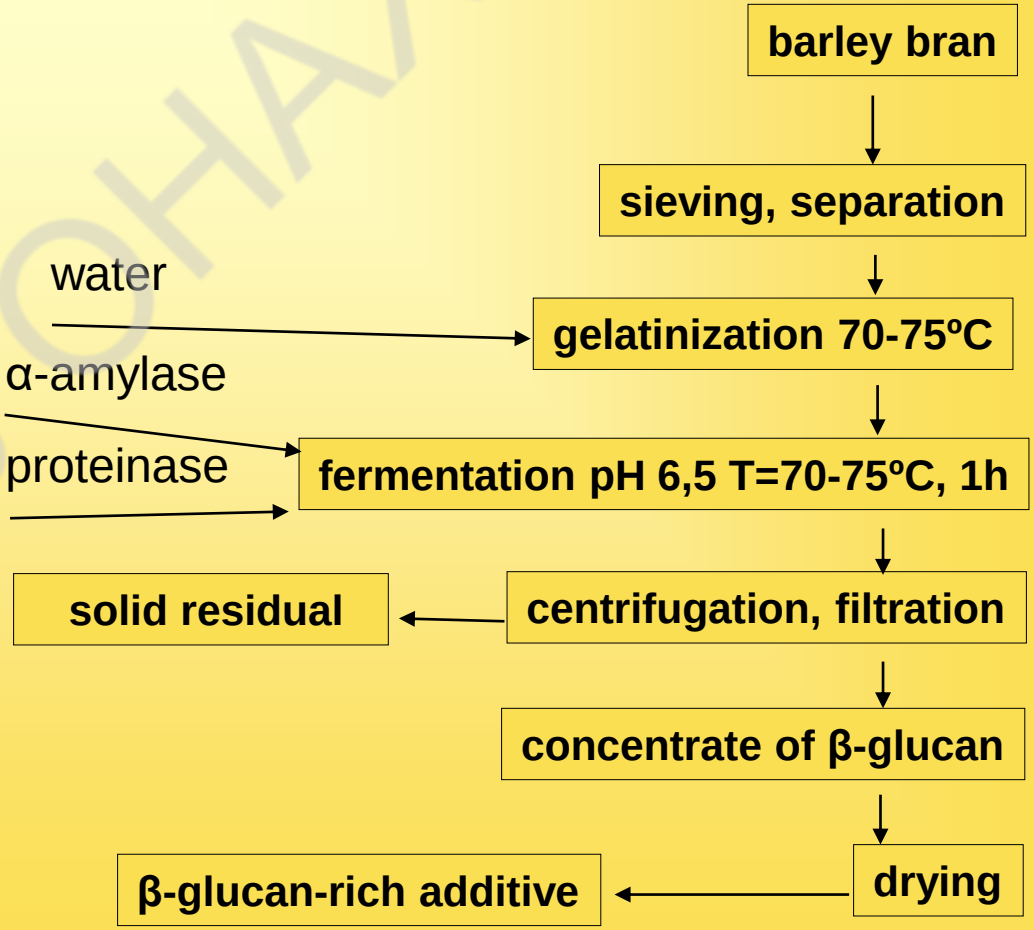
Preparation of β-glucan-rich additives using enzymatic methods

β-D-Glucan content of cereals of Ukraine (% dry weight basis)

Cereal	β-D-Glucan	
	Whole grain	Bran
Barley	8-10	10-16
Oats	5-8	7-9
Rye	2-3	4-5
Wheat	0,5-0,8	0,9-1,5
Corn	0,2-0,3	0,6-0,9
Rice	0,1-0,3	0,4-0,7



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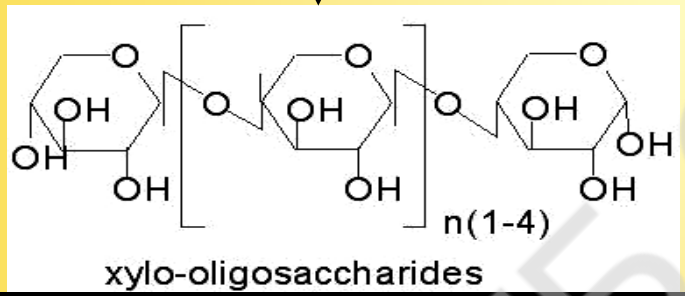
Enzymatic production of prebiotic oligosaccharides

Hulls, bran alkaline extraction and purification → **Xylan**

Xylan → hydrolysis β-xylanase



Components	XOS	Components	IMOS
Dry subst.	92,0	Dry subst.	80,4
Xylose	5,7	Panose	34,9
Xylobiose	16,3	Isomaltose	8,4
Xylotriose	22,1	Maltose	14,9
Xylotetraose	45,6	Glucose	24,7
Protein	3,2	Protein	14,2
Ash	2,7	Ash	1,3

Prebiotics are produsd from cereals e.g. xylooligosaccharides (XOS) and isomaltooligosaccharides (IMOS) by enzymatic biotransformations of polysaccharides

Bran → **starch**

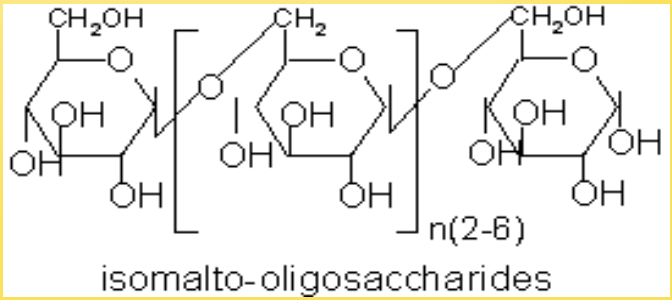
α-amylase

liquefaction → **dextrins**

hydrolysis → **maltose**

β-amylase

transglucosilation → α-glucosidase



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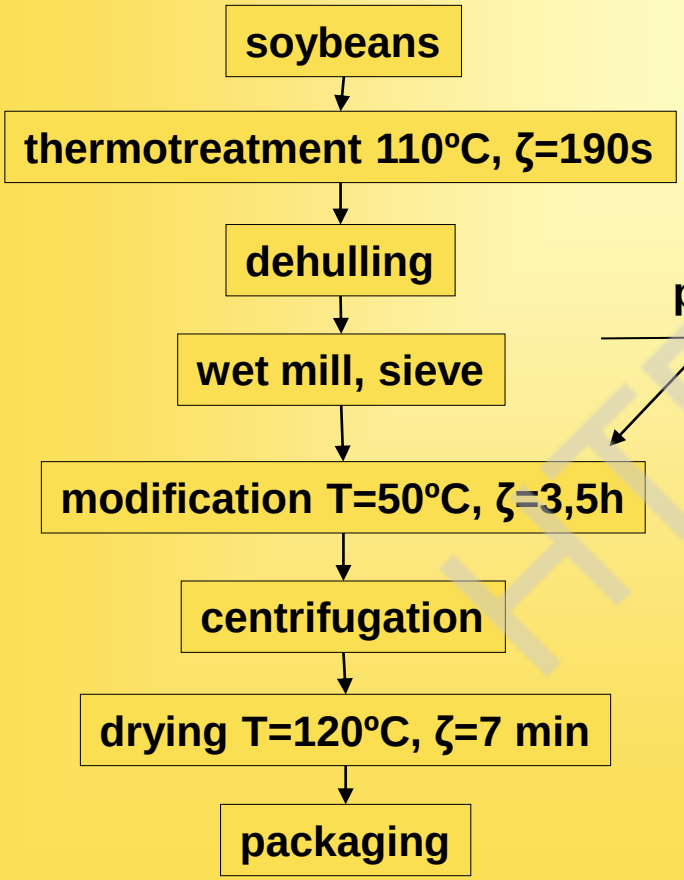
Improvement of soybean products technology by using endo – and exoenzymes (induced autolysis)



Functional properties

Product	Functional properties, %		
	Fat holding capacity	Stability of emulsion	Fat emulsifying properties
soybean flour (control)	74	43	42
modified soybean flour	115	70	64

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Conclusions

- **Cereals can be considered as functional foods even without enriching.**
- **By-products of grain processing, such as bran, farina and germ flakes, correspond to requirements of functionality to mach higher degree then the flour.**
- **The bran fractions may be used as natural source of dietary fibers, prebiotics, fermented cereal products, antioxidants.**
- **As the result, new biotechnological methods have been developed for reprocessing of grain raw materials and by-products in food and biologically active supplements, as well as enriching agents and functional foods: isolated of dietary fibers, β-glucans, fermented cereal products, cereal bioproducts, resistant starches, prebiotics, modified hemicelluloses, protein enriching agents.**

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Thank you for your attention