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CORN GERM OIL EXTRACTION BY A NEW ENZYMATIC PROCESS

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Aqueous enzymatic extraction of corn germ oil was investigated. Several commercial enzyme preparations (Gamanase 1.5 L, Pextinex Ultra SP–L, Celluclast 1.5 and SP–348) were used individually or in mixtures. The results have shown that the following operations should be applied as to increase the efficiency of enzyme activity: hydrothermal pretreatment of corn germ, grinding, enzymatic treatment and centrifugal separation of oil. A quite new procedure for oil extraction was developed as a technological phase in the course of integral corn processing in the starch technology. The economy of the process was preliminarily analyzed from the aspect of energy consumption.

Keywords: aqueous-enzymatic extraction, biotechnology, corn germ, corn germ oil, wet corn milling

The high content of essential fatty acids and tocopherols includes the corn germ oil in the group of oils with highest biological value. The presence of γ-tocopherol makes the corn oil more stable to oxidation than the sunflowerseed and many other edible oils. Usually, the corn oil is produced from corn germ after wet milling in the course of starch technology. Wet-milled corn germ contains more than 50% moisture and about 20% oil. KARLOVIĆ and co-workers (1988) report that the corn germ has to be dried to 2–7% moisture for processing by conventional procedure (pressing or combination of pressing and extraction). The dry corn germ contains 40 to 50% oil, depending on the corn type and the process used for corn germ separation.

The production of corn germ oil involves several technological problems. Long-term studies of corn-germ oil on our market have shown that the quality varies widely. The main cases are the deterioration processes which start during storage and steeping, as the result of lipoxidase activity and other enzymes present in the germ. These processes are difficult to be slowered down or to be prevented. Drying and conditioning are performed under adequate circumstances. A number of factors influence the quality of corn germ.

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Corn germ is characterized by the content of oxidation and some coloured products that are transferred to the oil during pressing and extraction making the oil refining difficult (VOLOTOVSKAJA et al., 1975; FAUR, 1981; KARLOVIĆ et al., 1985; KARLOVIĆ et al., 1988).

The conventional process is tedious, and in addition, the energy consumption is high, and the recovery of raw material is relatively low.

Screw presses are mainly used for pressing. Full-press expellers are used in small-scale plants. Probably due to the specific morphological structure of corn germ it is very difficult to maintain 5% residual oil content in the cake. LEIBOVITZ and RUCKENSTEIN (1983) report 6% residual oil in the cake after full-pressing. KARLOVIĆ and co-workers (1988) found up to 10% and even higher residual oil content in the cake. The residual oil content of the cake depending on the method of obtaining and processing corn germ is presented in Table 1 (REINERS, 1978).

Table 1

Oil content of corn germ cake and meal depending on obtaining and processing

Separation of		Residual oil content (%)
corn germ	oil	
Wet or dry milling	Full pressing	7–10
Wet milling	Pre-pressing + solvent extraction	1–3
Dry milling	Solvent extraction	1–2

Considering the specific energy consumption of cold pressing in case of different oil seeds, the corn germ proved to be the least economical as shown in Table 2 (STEIN, 1984).

It is evident from the presented data that the yield during corn germ processing is lower than that of other typical oil-bearing materials.

The separation of oil by pressing and extraction is difficult due to the specific morphologic structure and chemical composition of corn germ (KARLOVIĆ et al., 1991).

The solution of the above-mentioned problem is probably the improvement and optimization of the present processing procedure or the development of a new technology as to eliminate the shortages of the conventional method.

Table 2

Specific energy consumption during cold pressing of different raw materials

Raw material	Specific energy consumption kW_h/t
Rapeseed	30–35
Sunflowerseed	35–40
Safflowerseed	about 35
Linseed	35–40
Corn germ	about 50–55
Copra	40

An alternate way of oil production – the aqueous enzymatic extraction – has recently attracted interest. Due to the mechanical and enzymatic degradation of the cell walls, lipid bodies i.e. oil, as well as protein and carbohydrates are liberated from the cells (CHRISTENSEN, 1991).

Enzymatic oil extraction was applied to olives (CHRISTENSEN, 1991; DI GIOVACCHINO, 1991), rapeseed (KOFOD, 1988), coconut (MC GLONE & LOPEZ-MUNGUIA CANALES, 1986), linseed (OLSEN, 1988), palm mesocarp (CHEAH et al., 1990), avocado fruit (BUENROSTRO & LOPEZ-MUNGUIA CANALES, 1986), and plum kernels (PIČURIĆ et al., 1991). HITZE and co-workers (1975) were the first to describe the application of this process for corn germ. According to CHRISTENSEN (1991) the data on enzymes of corn germ cell structure degradation are insufficient, so this area is still a challenge for the scientists.

Our previous investigations (BOCEVSKA et al., 1991; BOCEVSKA et al., 1992; BOCEVSKA et al., 1993; KARLOVIĆ et al., 1993), showed that the efficiency of aqueous enzymatic oil extraction is influenced by several factors, as presented in Fig. 1.

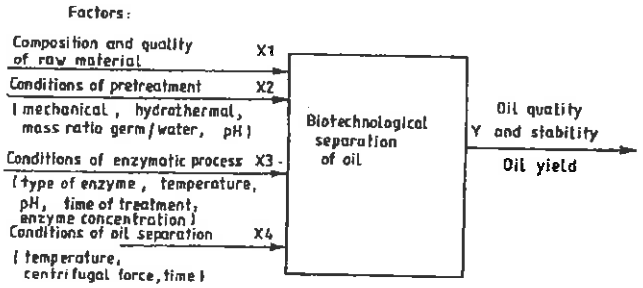

Fig. 1. Factors influencing the yield and quality of oil obtained by biotechnological separation from corn germ

The chemical composition of cell wall (which has to be ruptured) is of special importance. The available data have shown that the chemical composition of cell wall of different oil-bearing plants is rather different, particularly considering the polysaccharides (Table 3).

Table 3

Approximate composition of cell wall polysaccharides of some of the oil-containing crops

Polysaccharide components	Corn germ (%)	Rapeseed (%)	Coconut (%)
Pectic substances	< 1	39	–
Mannan	–	–	61
Galactomannan	–	–	26
Arabinogalactans	–	8	some
Cellulose	39	22	13
Hemicellulose:			
xyloglucan	–	29	–
arabioxylan	50	–	–
Other	10	2	–

According to CHRISTENSEN (1991), hemicellulose and cellulose are equally represented in corn germ cell walls. However, it was observed earlier (OLSEN, 1988) that the content of hemicellulose components is higher. The rupture of corn germ cell walls by enzymatic action is, therefore, a very serious problem. Namely, HOLLÓ (1988), considers the enzymatic degradation of lignine (hemicellulose) to be one of the biggest challenges of food and feed technology. A well-known fact is, also, that technological problems arise during enzymatic degradation of cellulose, due to the strong and stable structure of this substrate. The pathway of hydrolysis of cellulose to glucose is still not known completely. It seems that joint sequential action of three main enzymes present in the cellulose-complex is necessary for the hydrolysis of crystalline cellulose (HOLLÓ, 1988).

The complete hydrolysis of cellulose to glucose is not necessary for the aqueous enzymatic oil extraction. Namely, due to the enzymatic treatment the cell wall gets fragmented, the cell content is transferred into the polar water phase. As oil is nonpolar, it can be separated by centrifugation or some other separation procedure.

The economic effect of aqueous enzymatic extraction of rapeseed oil is positive (KOFOD, 1988). The optimization of aqueous enzymatic procedure during coconut processing could also yield economically available results (BARRIOS et al., 1990).

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2	–

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lts (BARRIOS et al., 1990).

The aim of the present work was to investigate the possibility of application of some commercial enzymes to obtain oil from corn germ by aqueous enzymatic extraction.

1. Materials and methods

1.1. Material

Corn germ used in the experiments was obtained by wet milling in a modern starch plant by hydrocyclone separation. Samples were taken after dewatering by pressing. The germ thus obtained was preserved in a frozen state at −18 °C to the day preceeding the experiment, when it was defrosted in the refrigerator at +4 °C. Basic chemical composition of the wet and dry corn germ is presented in Table 4.

Table 4

Chemical composition of corn germ

Composition	%
a Wet corn germ:	
moisture	53.4
oil	19.1
b Absolutely dry matter	
oil	41.0
proteins	14.9
starch	6.2
pectin	0.7
cellulose[a]	11.2

a: calculated on fat-free material

The characteristics of the applied commercial enzymes and samples obtained from the producers are shown in Table 5.

Table 5

Enzymes used in the experiments

Enzyme	Microorganism	Main activity	Declared activity
Pectinex Ultra SP-L[a]	*Aspergillus niger*	– Polygalacturonase – Pectinesterase – Pectintranseliminase – Hemicellulase	26.000 PG (pH = 3.5 T = 20 °C)
Gamanase[b]	*Aspergillus niger*	– Hemicellulase (endoenzyme) Galactomanase	1.500,000 VHCU g^{-1} (Viscosity Hemicellulase Ac.)
SP-348[a]	*Hemicola insolens*	– Cellulase (egzoenzyme)	–
Celluclast 1.5 L[b]	*Trichoderma reseei*	– Cellulase (endoenzyme)	1500 NCU g^{-1}

[a]: Novo Ferment AG, CH-4243 Dittingen, Switzerland
[b]: Novo Industri A/S, Copenhagen, Denmark

The amounts of the enzymes used in the experiments are presented in Table 6.

Table 6

Dosage of enzymatic preparations in the experiments

No.	Name	Calculated on germ mass %
1	Celluclast 1,5 L	2
2	Celluclast 1,5 L + SP 348	1+1
3	Gamanase 1,5 L	2
4	SP-348	2
5	Gamanase 1,5 L + Pectinex Ultra SP-L	1+1

1.2. Procedure

To obtain oil from corn germ, the following operations were carried out (Fig. 2):

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Main activity	Declared activity
Polygalactu-ronase Pectinesterase Pectintrans-eliminase Hemicellulase	26.000 PG (pH = 3.5 T = 20 °C)
Hemicellulase (endoenzyme) Galactomanase	1.500,000 VHCU g^{-1} (Viscosity Hemicelu-lase Ac.)
Cellulase (gzoenzyme)	–
Cellulase (endoenzyme)	1500 NCU g^{-1}

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Calculated on germ mass %
2
1+1
2
2
1+1

g operations were carried out

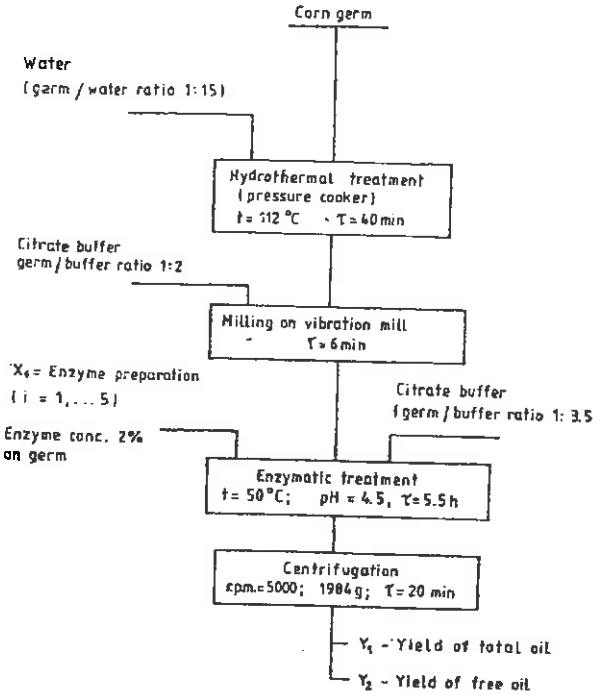

Fig. 2. Plan of experiments $Y_i = f(X_i)$

1.3. Analytical methods

The content of total and free oil was determined using the method developed by BOCEVSKA (1993).

2. Results and discussion

2.1. Analysis of the possible aqueous enzymatic extraction in the integral processing of corn germ in corn wet milling

The flow sheet of the conventional oil obtaining method presented in this work is given in Fig. 3.

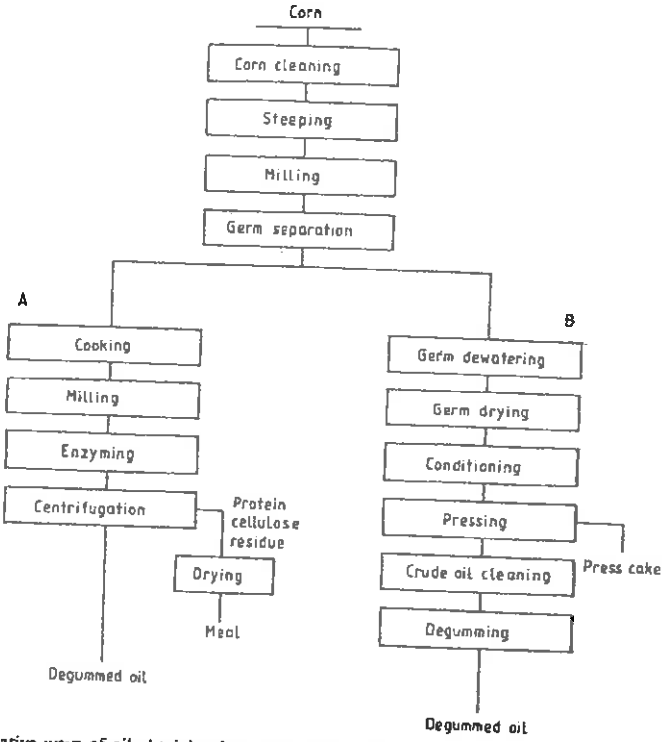

Fig. 3. Alternative ways of oil obtaining from corn germ in the course of integral starch processing of corn. A: new corn germ processing; B: conventional corn germ processing

The investigation of the effect of enzymes on ground corn germ clearly indicates that high oil yield can be obtained following the sequence of operations shown in Fig. 3 and applying the enzyme Celluclast (Fig. 4).

Our investigations show that the yield of oil obtained by the new procedure in even higher than that of obtained by the conventional method. However, the economy of this technological procedure can be estimated after the economic analysis of the process.

The analysis was performed assuming that the oil yield is the same in both processes. In that case, the economy is affected by the cost of energy and enzyme.

The data for the analysis, i.e. the specific consumption of steam and energy for the operations of the conventional procedure were supplied by a modern starch factory, whereas the data for the new biotechnological process were found in literature (HOFMANN, 1989; HAGENMAIER et al., 1975; STEIN, 1984).

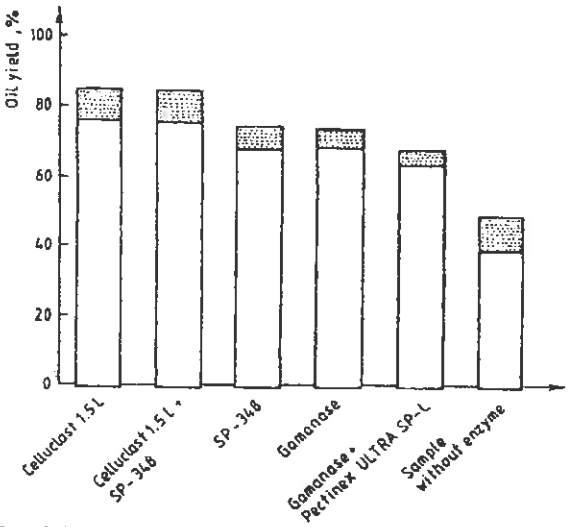

Fig. 4. Effect of different enzymatic preparations on corn oil yield, □: Free oil; ▨: emulsion

The results presented in Table 7 point out that the cost of enzymes is the key--factor which completely annuls the effects achieved by energy saving during the biotechnological procedure. For that reason, the optimization of enzyme consumption will be the aim of our further investigations. Probably the enzymatic reaction should be performed with smaller amounts of enzymes. However, such experiments were not performed till now, as we were engaged with the optimization of other parameters of enzymatic reaction.

The economic analysis containing a complete material balance and the price of the finished product is still not possible. However, there are several alternative ways for the improvement of economy of the biotechnological procedure. BARRIOS and co-workers (1990) report on the possibility of repeated use of enzymes with water recirculation. It is possible to solve the processing of by-products (protein flour, carbohydrate solution) more economically and adequately. The drying of these products is not the only way of their valorization. BOCEVSKA (1993) considers that the processing of by-products obtained in the first cycle of enzymatic process should be treated in a different way. It may be possible to join the obtained carbohydrate fraction, containing the enzyme after the recirculation, and the starch hydrolyzate or some other substrate, in the process of fermentation.

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Table 7

Analysis of specific energy consumption of corn oil extraction by conventional and aqueous enzymatic extraction procedure

Operation	Conventional[a]		Biotechnological	
	Steam (ton/ton)	Electricity (kWh/t)	Steam (ton/ton)	Electricity (kWh/t)
Corn germ dewatering by pressing	–	16.8	–	–
Corn germ drying	1.6	24.0	–	–
Cooking	–	–	0.2	5.0
Germ milling	–	–	–	20.0
Conditioning	0.8	9.6	–	–
Full pressing	–	80.0	–	–
Enzymatic treatment	–	–	0.2	5.0
Crude oil "cleaning" (settling, filtration)	1.6	19.0	–	–
Oil centrifugation	–	–	–	4.5
Drying or protein-cellulose residue	–	–	1.0	9.0
Oil degumming	0.1	4.5		
Total Energy:	4.1	153.9	1.4	43.5
Price in DM/t	225.0	23.1	70.0	6.6
Consumption and price of enzymes	–	–	20 kg × 27.5 = 550 DM	
Total (DM/t)	248.1		626.6	

[a] Plant Data: Starch Factory "IPOK" Zrenjanin, Yugoslavia
[b] Novo Information, Personal communication, 1994
Electric energy 0.15 DM/KWh;
steam 50.0 DM/t;
enzymes (Celuclast 1.5L)[b] 27.5 DM/kg

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Biotechnological	
Steam (ton/ton)	Electricity (kWh/t)
–	–
–	–
0.2	5.0
–	20.0
–	–
–	–
0.2	5.0
–	–
–	4.5
1.0	9.0
1.4	43.5
70.0	6.6
20 kg × 27.5 = 550 DM	
626.6	

The characteristics of the obtained oil are more favourable compared to the conventionally obtained oil. Namely, the quality of the oil obtained by the new procedure is equal to the quality of degummed oil intended for physical refining. Practically, it means one operation less in the processing of the oil. Further, it has been proved that due to the work in aqueous media, simultaneously to the liquefaction of cell structure, the phospholipids are separated from the oil. BOCEVSKA (1993) reports that such oil contains about 8 ppm of phosphorous.

The starch processors have a significant experience with the application of enzymes, in contrast to oil industry. The introduction of aqueous enzymatic treatment of corn germ into the integral cereal-oil processing would be beneficial.

We are indebted to F. M. CHRISTENSEN of Novo Nordisk Ferment Ltd., Switzerland for his generous gift of the enzyme sample and the pertinent literature.

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