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The effects of enzymes on fat content and texture of French fries

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Abstract

The purpose of the present investigation was to study the changes in the microstructure of potato cells during French fries processing with the use of enzymes and to find the impact of the enzymes on fat content and texture of French fries. The samples for laboratory studies were of potato strips and French fries, collected from five locations of the technological line.

The results obtained in the study show that pectolytic and hemicellulytic activities of enzymes used for French fries production improve the quality of the finished product, especially fat content, after the first and the second stage of frying, which was 10–20% lower in treated than in untreated French fries. The microstructures of treated and untreated French fries varied; the enzymes caused destruction of the cell wall.

Keywords: French fries; Enzymes; Fat content; Texture

1. Introduction

Texture of fried potato products, including French fries, is one of major characteristics for describing their quality. It can be modified during technological processing, but primarily depends on chemical composition of the raw material. For this reason, French fries manufacturers select suitable potato cultivars, with appropriate dry substance and starch contents (Lisińska, 2004; Zgórska & Frydecka-Mazurczyk, 2002). The data in the literature also show that the sensory value of French fries can also be influenced by other compounds present in potato tubers. Besides starch, non-starch polysaccharides, such as pectic compounds, especially soluble pectins and protopectins, are known to be texture-forming substances (Kita, 2002; Tajner-Czopek, 2003). These compounds occur in intracellular spaces as pasting agents for non-lignified plant cell walls. In the cell wall of a plant tissue, the role of this fraction is to add stiffness and strength to the structure (McComb & McCready, 1952). Turgor of fresh plant tissues is, among things, dependent on proportions and distribution of chemical components in the cell wall and intracellular spaces. These components, apart from the pectins mentioned, above also include cellulose, hemicellulose and lignins.

Heat treatment (blanching, pre-drying and frying) during potato processing causes the occurrence of a "skeleton" in potato tissue, containing various proportions of carbohydrate compounds, responsible for the texture of French fries (Gołubowska & Lisińska, 2003; Lisińska & Gołubowska, 2005). The mealy or mashy texture of French fries is connected with starch swelling and pasting as well as stability of pectic compounds in the cell walls. Pectic substances and starch present in the cells exert antagonistic effects on the texture. When starch swells, the cells become larger, and consequently, they become separated, while pectic compounds prevent this phenomenon, due to their cohesive effect (Andersson, Gekas, Lind, Oliveira, & Oste, 1994).

Frying oil is another important raw material, apart from potato, used for French fries manufacturing. An industrial half-product (French fries after one-stage of frying) contains about 4% of fat and 10% of fat after a second-stage

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(Lisińska, 2004; Lisińska & Leszczyński, 1989;Talburt & Smith, 1987). French fries manufacturers are interested in reducing fat content of the product because of the high prices of oil and quality requirements of consumers, who prefer low-fat French fries of high sensory value and with the flavour and aroma of freshly-baked potato, uniform in colour, crispy texture of the skin and mealy flesh. Fat content of French fries is influenced by the properties of the raw material; namely, potato cultivar, dry matter and carbohydrate compound contents (Lisińska & Leszczyński, 1989; Tajner-Czopek, Kita, Pęksa, & Lisińska, 2003) as well as technological parameters used for blanching, predrying and frying (Gołubowska & Lisińska, 2003;Kita, 2002;Tajner-Czopek, 2003). In industrial practices, the texture of French fries is improved by various temperatures of the blanching water and blanching procedure, with the use of one, two or three blanchers. Besides, new attempts have been made, with the use of starch paste additives and calcium salts, to improve blanching (Califano & Calvelo, 1987; Tajner-Czopek, 2003). In recent years, the use of enzymes containing asparaginase in potato processing has been extensively studied, so as to reduce the content of toxic acrylamides developed during frying at high temperatures (Kita, Brathen, Knutsen, & Wicklund, 2005; Predeschi, Kaack, & Granby, 2004). Enzyme preparations containing pectinase may cause changes in potato microstructure and, consequently, they may influence oil absorption and texture of French fries. The purpose of the present investigation was to study changes in the microstructure of potato cells during French fries processing with the use of enzymes and to find their impact on fat content and the texture of French fries.

2. Materials and methods

2.1. Materials

The laboratory studies were carried out with potatoes of Innowator and Santana varieties, received from a storage house belonging to a company producing French fries. Potato tubers were washed, peeled and cut into strips (1 cm × 1 cm × 6 cm). After washing in cold water, potato strips were dried on blotting paper and blanched in water at 75 °C for 10 min. Next, the strips were drained on a sieve, and afterwards, divided into two portions and kept in water for 20 min: portion 1 in cold water; portion 2 in water at 40 °C containing enzyme preparation (Pectinex Ultra SP-L) with pectolytic and hemicellulytic activities (Novozymes A/S, Bagsvaerd, Denmark). Pectinex Ultra SP-L is a crude enzyme preparation from *Aspergillus aculeatus* obtained from Novozymes A/S (Bagsvaerd, Denmark). This enzyme preparation contains pectolytic and hemicellulytic activities and the declared activity is 9500 PGU/ml. One PGU is the viscosity reduction obtained by hydrolysis of polygalacturonic acid measured relative to an enzyme standard at 30 °C and pH 3.5. Optimal working conditions are 35–40 °C and pH 3.5–6.5. The two portions of potato strips were fried in rapeseed oil (3.5 l per 200 g of potato strips) in the same manner. At the first stage, potatoes were fried at 175 °C for 1 min. After cooling, the French fries were frozen to −18 °C. At the second stage, the French fries were fried at the same temperature for 5 min.

All experiments were performed in four replications and the present results show average values obtained in the study.

2.2. Analysis

10 minutes after removal of the potato strips from the blancher or French fries from the fryer, the samples (20 potato strips or French fries) were collected, from each series, for texture determinations. Immediately after the samples were collected, the texture of potato strips and French fries was determined using an Instron 5544 apparatus connected to a computer equipped with rectangular attachment for cutting. The velocity of the head with the attachment was 250 mm min^{-1} with a 200 kg load cell. The measurements were taken for determining maximum shear force (F_{max}) necessary to cut the potato strips. Each measurement was conducted on 20 potato strips or French fries. Timing for the texture measurements was strictly determined and exactly the same with each sample.

Changes in the structure of potato tissue were determined in strips after trimming in cold water or water (40 °C) containing enzymes and in French fries after the first step of frying, using a Leo-435VP scanning electron microscope. The samples (cross-section immediately under crust) for SEM were fixed by freezing in liquid nitrogen and spraying with gold.

Fat content of the French fries was determined using Soxhlet's method (AOAC, 1995). Fat was extracted using a Büchi B-811 Universal extraction system (Switzerland).

2.3. Statistical analysis

The data were analyzed statistically using a Statistica 6 programme (2001). For comparison, the results obtained were analyzed using one-way analysis of variance with the application of Duncan's test ($P < 0.05$).

3. Results and discussion

The material taken for the present study consisted of Innowator and Santana potato varieties, the most common cultivars in Central Europe used for French fries production. Table 1 shows dry matter and starch content of potatoes before peeling. The potatoes of the Santana variety contained 1.5% more dry matter and starch than did potatoes of the Innowator variety.

As can be seen in Tables 2 and 3, dry matter content of the potatoes at the first stage of processing hardly changed. Dry matter contents of the potatoes cut into strips, blanched and trimmed in cold water or in water (40 °C) containing enzymes were about 21% (Innowator) and

Table 1
Contents of dry matter and starch in potato tubers of Innowator and Santana varieties

Variety	Dry matter (%)	Starch (%)
Innowator	22.32	17.21
Santana	24.00	18.89

22.5% (Santana). Final processing (frying) resulted in significant dehydration of the product. French fries after the first stage of frying contained about 25.5% (Innowator) and 30% (Santana) of dry matter. Dry matter contents of the French fries ready for consumption (after second stage of frying) was 55–65%.

The use of enzyme preparations for French fries production affected fat content of both the half finished and the finished product. When potato strips were trimmed in water (40 °C) containing enzyme preparations with pectolytic and hemicellulytic activities, the resulting product was lower in fat than were French fries made with no enzyme addition. Half-products made from the Innowator cultivar were 25% lower in fat content, in conversion to 100 g of dry matter, while those of the Santana cultivar were 10% lower in fat. The French fries produced with the use of enzyme preparations contained 22% (Innowator) and 8% (Santana) less fat than those made with no enzyme addition.

When French fries are fried under industrial conditions, at the initial stage, immediately after potato strips are immersed in hot oil (160–185 °C), rapid pasting of starch present on the surface layer occurs. The pasted layer of starch protects flesh from excessive fat penetration. Starch pasting begins earlier, during blanching and pre-drying (Talburt & Smith, 1987). Frying brings about water evaporation from the external, and next the inner portion of French fries, and the water vapour protects the inner layer from oil penetration until the temperature of the product is decreased. Cooling of the product allows the excess of fat to get into the inner portion through canals made up by the water evaporating during frying (Mellema, 2003; Bouchon, Hollins, Pearson, Pyle, & Tobin, 2001; Saguy & Pinthus, 1995).

Fig. 1 shows the mechanism of oil uptake by French fries produced with and without enzymes. During cooling of control samples of French fries (Fig. 1a), with well preserved cellular structure under the crust, fat penetrated the deeper layers of potato strips through the canals made up by the water evaporating during frying. The use of Pectinex Ultra (Fig. 1b) weakened the cell walls of the potato, which break during frying, allowing starch release. Pasting starch formed an unpermeatable layer, preventing fat penetration into the inner portion of the French fries.

In the present investigation, changes in fat content of French fries produced with and without enzymes were studied with regard to potato tissue structure. Figs. 2–5 show some changes in the microstructure of the strips and French fries resulting from the use of enzyme preparations after blanching. Fig. 2 shows a cross-section of potato strips before frying (no enzymes), with clearly seen undam-

Table 2
Contents of dry matter and fat in potato strips during French fries processing (Innowator)

Stage	Dry matter (%)	Fat content	
		(%)	(g/100 g d.m.)
Potato strips	22.19	–	–
Strips after blanching	21.09	–	–
Strips after trimming in cold water	19.90	–	–
Strips after trimming in enzyme	20.55	–	–
French fries after stage I of frying (without enzyme)	26.11	2.34b	8.96b
French fries after stage I of frying (with enzyme)	25.30	1.66a	6.56a
French fries after stage II of frying (without enzyme)	65.45	19.42B	29.67B
French fries after stage II of frying (with enzyme)	63.51	14.61A	23.00A

Different letters (a,b) indicate significant differences among results of stage I of frying ($P \leqslant 0.05$). Different letters (A,B) indicate significant differences among results of stage II of frying ($P \leqslant 0.05$).

Table 3
Contents of dry matter and fat in the potato strips during French fries processing (Santana)

Stage	Dry matter (%)	Fat content	
		(%)	(g/100 g d.m.)
Potato strips	23.78	–	–
Strips after blanching	23.09	–	–
Strips after trimming in cold water	22.52	–	–
Strips after trimming in enzyme	22.62	–	–
French fries after stage I of frying (without enzyme)	29.82	2.90a	9.73a
French fries after stage I of frying (with enzyme)	30.63	2.69a	8.78a
French fries after stage II of frying (without enzyme)	60.21	14.48B	24.05B
French fries after stage II of frying (with enzyme)	55.86	12.32A	22.05A

Different letters (a,b) indicate significant differences among results of stage I of frying ($P \leqslant 0.05$). Different letters (A,B) indicate significant differences among results of stage II of frying ($P \leqslant 0.05$).

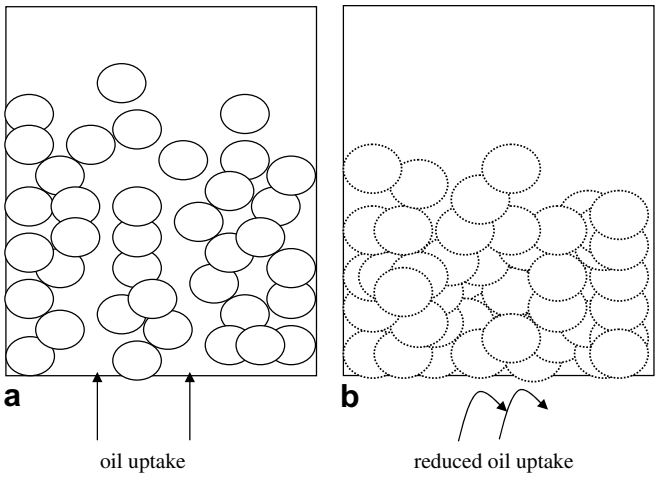

Fig. 1. Mechanism of oil uptake by French fries produced with and without use of enzyme.

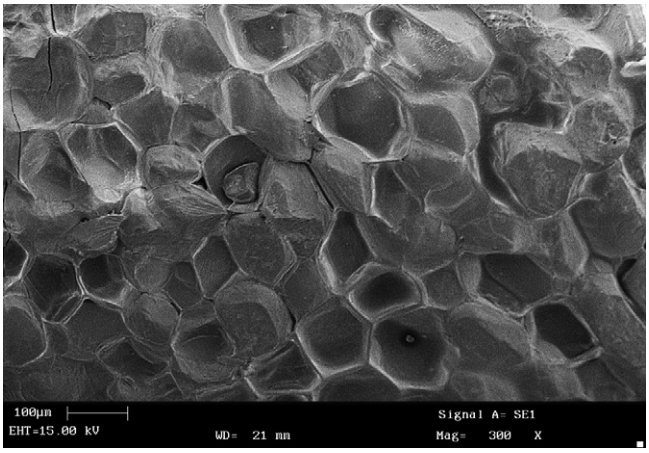

Fig. 2. The strips (cross-section immediately under crust) after trimming in cold water (without enzymes).

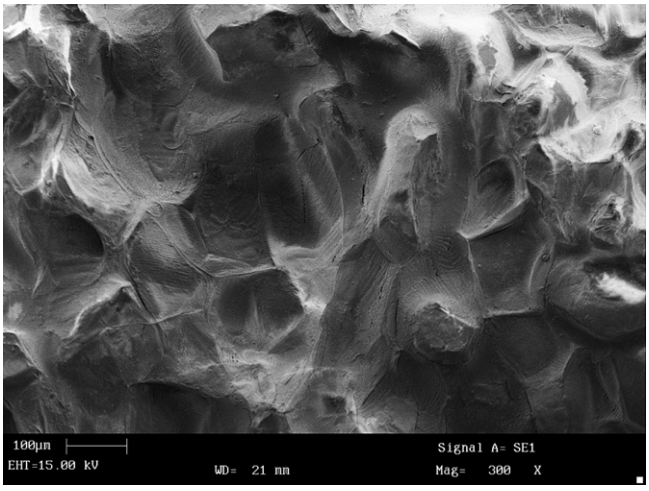

Fig. 3. The strips (cross-section immediately under crust) after trimming with water (40 °C) with enzymes.

aged cell structure. In contrast, Fig. 3 shows damaged potato tissue after 20 min treatment of potato strips in water containing enzymes. Further changes in the tissue

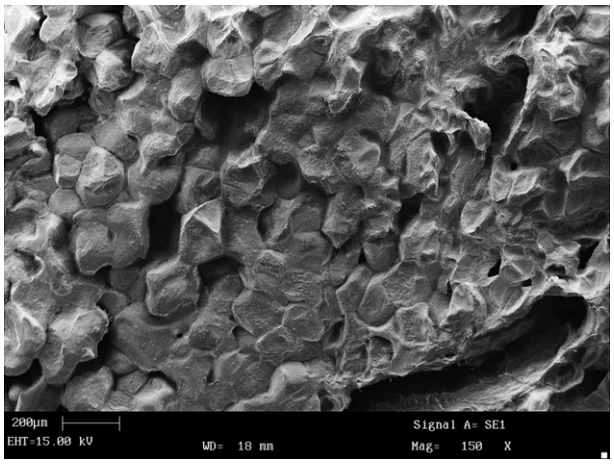

Fig. 4. French fries (cross-section immediately under crust) after first step of frying (without enzymes).

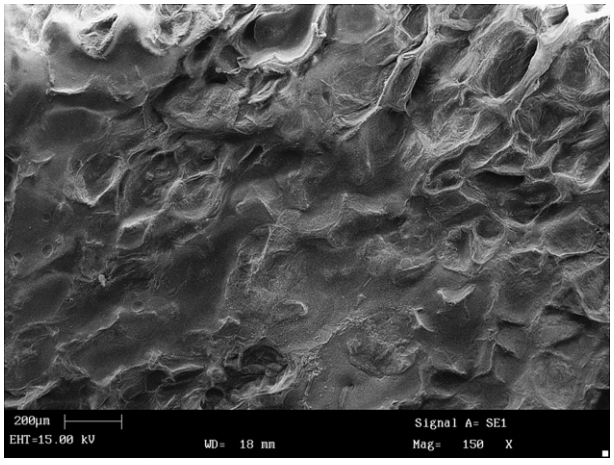

Fig. 5. French fries (cross-section immediately under crust) after first step of frying (with enzymes).

structure, resulting from pectolytic and hemicellulytic enzyme activities in fried French fries, can be seen in Fig. 5. The cross-section of French Fries produced with no addition of enzyme preparations shows that the cell structure has not changed (Fig. 4). Higher amounts of fat in French fries produced without enzyme preparations than in those obtained with the use of enzymes may have been a result of fat penetration from the skin (outer layer) of French fries to the outer layer through the canals developed between the cells. Destruction of the cell structure caused by enzymes (Figs. 3 and 5) suppressed penetration of fat into the internal portion of French fries, immediately after they had been taken out of the frying oil.

Figs. 6 and 7 show changes in the texture of potato strips during French fries production. Blanching reduced the hardness of potato strips and further reduction was observed after 20 min when potato strips were kept in water (40 °C) containing enzymes, in comparison with untreated potato strips. The use of pectolytic and hemicellulytic enzymes resulted in the destruction of the cell structure

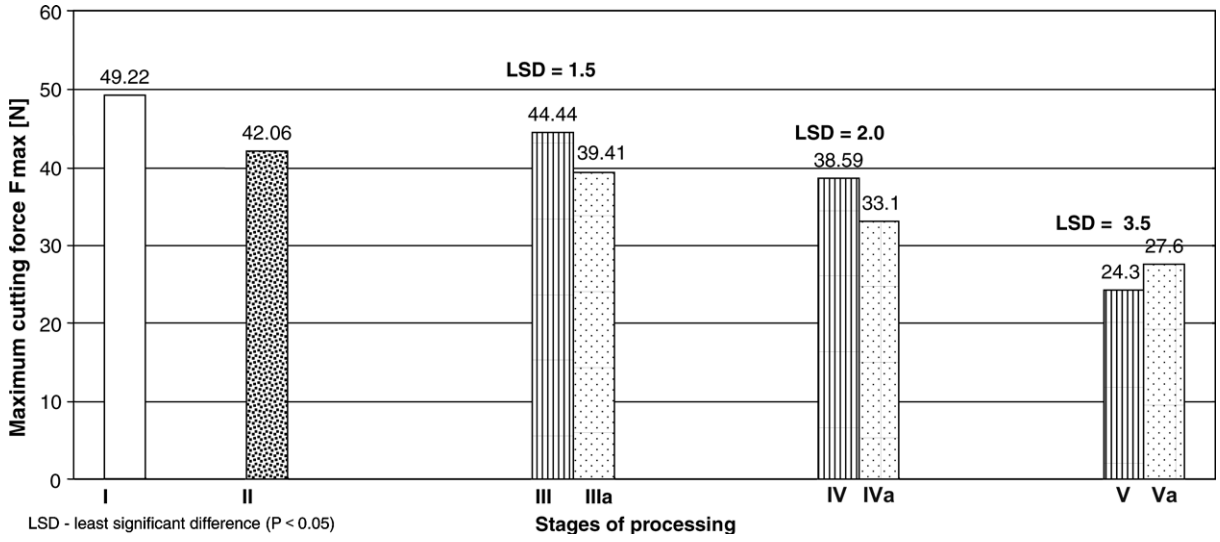

Fig. 6. Texture [N] of potato strips and French fries during French fries processing (Innowator). I – potato strips, II – strips after blanching, III – strips after trimming in cold water, IIIa – strips after trimming in enzyme, IV – French fries after stage I of frying (without enzyme), IVa – French fries after stage I of frying (with enzyme), V – French fries after stage II of frying (without enzyme), Va – French fries after stage II of frying (with enzyme).

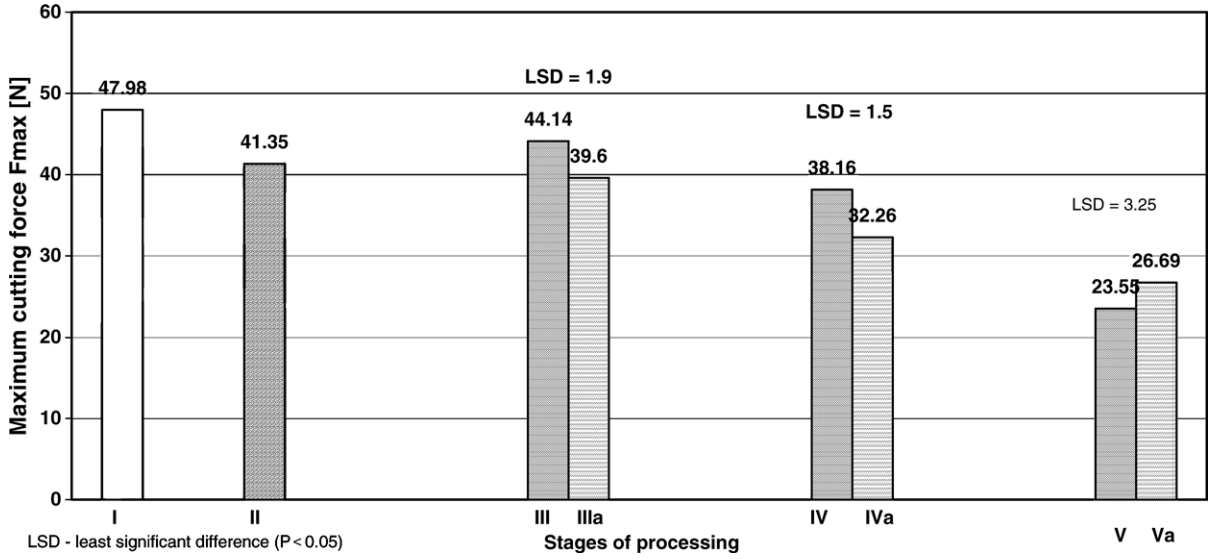

Fig. 7. Texture [N] of potato strips and French fries during French fries processing (Santana). I – potato strips, II – strips after blanching, III – strips after trimming in cold water, IIIa – strips after trimming in enzyme, IV – French fries after stage I of frying (without enzyme), IVa – French fries after stage I of frying (with enzyme), V – French fries after stage II of frying (without enzyme), Va – French fries after stage II of frying (with enzyme).

and subsequent decrease in N force necessary to cut a strip. The hardness of French fries at the first stage of frying was decreasing, but harder were those untreated with the enzymes. The differences in the hardness of French fries (treated and non-treated with Pectinex Ultra) after stage II of frying were not significant.

4. Conclusions

The results obtained in the study show that pectolytic and hemicellulytic activities of enzymes used for French fries production improve the quality of the finished product, especially fat content, after the first and the second stage of frying, which was 10–20% lower in treated than in untreated French fries. The microstructure of treated and untreated French fries varied, i.e., the enzymes caused destruction of the cell wall.

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