Available online at www.sciencedirect.com
SCIENCE DIRECT®
Food Chemistry 93 (2005) 681–687
Food Chemistry
www.elsevier.com/locate/foodchem

Structural changes of potato tissue during French fries production

Grażyna Lisińska *, Grażyna Gołubowska

Department of Food Storage and Technology, Faculty of Food Sciences, Agricultural University of Wrocław ul. C.K. Norwida 25, 50-375 Wrocław, Poland

Received 28 June 2004; received in revised form 20 October 2004; accepted 20 October 2004

Abstract

The purpose of the study was to determine some changes in the structure of potato tissue and the contents of non-starch polysaccharides and lignin in potatoes at particular stages of French fries production. The samples for laboratory studies were taken from potato tubers, strips and French fries collected from six locations of the technological line. Immediately after the samples were collected from the processing line, the texture of potatoes was determined using an Instron 5544. Structural changes in the tissue were determined using a Leo-435VP scanning electron microscope. Dry matter and non-starch polysaccharide contents were determined in the samples of processed potatoes. It was found that the texture of potato was changing during the technological process due to water losses and damages of potato tissue and consequent changes in non-starch polysaccharides and lignin. The greatest changes in potato tissue resulted from thermal processes: blanching, pre-drying and frying. Increases of non-starch polysaccharide and lignin contents were observed during these processes, owing to water losses in potato strips. The ultimate texture of French fries was developed during frying, by penetration of fat primarily into the external layer of strips.

Keywords: Potato tuber; French fries; French fries processing line; Tissue structure; Texture; Non-starch polysaccharides; Lignin

1. Introduction

Processing of plant raw materials causes irreversible changes in the tissues of fruit and vegetables. These changes are particularly visible after heat treatment, and their intensity depends on temperatures during blanching, drying and frying. Turgor of fresh plant tissues depends, among others, on ratios and distribution of chemical constituents in the cell wall and intracellular spaces. These constituents include: cellulose, hemicelluloses and pectins, generally referred to as non-starch polysaccharides (NSP) and lignin (Fennema, 1996). The cellular structure of external tissues of vegetables is partially damaged during blanching, and besides, the content of pectic substances is reduced, proteins are denatured, enzymes are inactivated and chemical constituents soluble in water are partially washed out (Jeremiah, 1996).

Apart from starch, texture-forming components of potatoes are NSP and lignin (Andersson, Gekas, Lind, Oliveira, & Oste, 1994), which account for almost one half the non-starch dry matter of the potato (Lisińska & Leszczyński, 1989). These compounds, not only influence the nutritive value of the product, but also the organoleptic features, especially the texture. The technological parameters used during processing also affect the content and composition of NSP and lignin. Thermal processes (blanching, pre-drying and frying) during French fries manufacturing cause the occurrence of a "skeleton" (consisting of varied proportions of carbohydrate compounds) in potato tissue, which is likely responsible for the texture of the finished

* Corresponding author. Tel.: +48 71 320 5239; fax: +48 71 320 5221.
E-mail address: lisinska@wnoz.ar.wroc.pl (G. Lisińska).

0308-8146/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2004.10.046

product (Gołubowska & Lisińska, 2003). In recent years, extensive studies have been carried out on the microstructure of food products, using electron microscopy for a better knowledge of textural properties of such products. Identification of the basic components of the microstructure of the raw material and half-products obtained at a given stage of French fries production, along with the content of NSP, will expand our knowledge of their texture-forming properties.

The purpose of the present study was to determine some changes in the structure of potato tissue and NSP and lignin contents of potatoes at a given stage of French fries production.

2. Materials and methods

2.1. Samples

The samples collected for laboratory studies consisted of potato tubers, potato strips and French fries (2 kg each) from six locations on the French fries processing line. Sample 1 consisted of potatoes before peeling, sample 2 steam-peeled potatoes, sample 3 potato strips (0.7 cm × 0.7 cm) by hydro-cutting, sample 4 after blanching at 80 °C for 5.0 min, sample 5 pre-dried potato strips at 37 °C for 6.0 min, and sample 6 French fries after frying at 180 °C for 7 min.

2.2. Analysis

Immediately after the samples were collected from the processing line, the texture of potatoes was determined using an Instron 5544 apparatus connected to a computer equipped with a rectangular attachment for cutting. The velocity of the head with the attachment was 250 mm/s. The measurements were taken for determining maximum shear force (F_{max}) necessary to cut the potato strips.

Changes in the structure of potato tissue were determined in potato tubers, strips and French fries, using a Leo-435VP scanning electron microscope. The samples for SEM were fixed immediately after handling, by freezing in liquid nitrogen and spraying with gold. NSP and lignin contents were determined by the Dever, Bandurski, and Kiviliaan (1968) method, modified by Jaswal (1970) and Tajner-Czopek et al. (1997) after freeze–drying of the potato samples.

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 ($P \leqslant 0.05$).

3. Results and discussion

Table 1 shows that dry matter content of potatoes did not change at the initial stages of processing. Both the raw material and peeled, cut and blanched potatoes contained about 21% of dry matter. The final processes of French fries manufacturing caused partial dehydration of potato strips. A half-product after pre-drying contained 25% of dry matter and French fries ready for consumption contained 55% of dry matter.

During French fries processing, the structure of potato tissue is markedly and irreversibly changed. Figs. 1–8 show some changes in the microstructure of the raw material at consecutive stages of processing. Fig. 1 shows the cross-section of a potato tuber with a thin layer of skin and a group of flesh cells with starch granules. The cells of the skin are compact, have no starch granules and resemble "cork" structure. At the same time, the contents of NSP and lignin were changing in potato tubers, half-products and French fries (Table 1) as also was the texture of the processed potatoes (Fig. 9). There are few literature reports on changes on non-starch polysaccharide and lignin contents of potatoes, half- and finished potato products resulting from technological processing. In general, the authors study the changes occurring during one stage of processing, e.g. peeling or blanching. Lisińska and Leszczyński (1989) report that the sum of NSP and lignin makes up almost half the non-starch dry matter content of the potato. Total content of these compounds in potato dry matter is varied and amounts to 8.58% (Anderson & Bridges, 1988), 6.70% (Englyst & Hudson, 1996) and from 6.16% to 7.28%, depending on potato cultivar (Tajner-Czopek, Kita, Rytel, & Gołubowska, 2002). In the present study, NSP and lignin content of dry matter of the raw material before peeling was about 10.9%.

One of the first stages of potato processing is peeling. Kita (2002) and Garrote et al. (2000) report that the compounds present in NSP and lignin content are subject to quantitative changes during peeling. Kita (2002) reports that the quantity of NSP and lignin decreased by 30% after peeling by a carboround method and greatest losses were observed in the cellulose fraction (from 70% to 40%) and lignin (about 30%). In the present

Table 1
Content of dry matter and non-starch polysaccharides (NSP) and lignin in potato tubers during French fries processing

Samples	Dry matter (%)	NSP and lignin (% d.m.)
Potato not peeled	21.0a	10.9a
Potato after peeling	22.0a	11.1a
Potato after cutting	20.7a	10.8a
Strips after blanching	21.2a	15.8b
Strips after pre-drying	24.8b	15.8b
French fries after frying	55.3c	17.1c

a–d, significant differences; $P \leqslant 0{,}05$.