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# Changes of polysaccharide content and texture of potato during French fries production

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**Abstract**

The purpose of the present study was to determine the changes in non-starch polysaccharide and lignin contents of potato during French fries production and also the relationship between the texture of the finished product and half-products, as a result of processing at each stage under investigation. The samples for laboratory studies were taken from potato tubers, strips and French fries collected from nine locations of a technological line. The greatest changes in non-starch polysaccharide content and texture of potatoes resulted from blanching and frying. The texture of French fries was mainly affected by pectin and cellulose. The texture of French fries can be predicted from the measurements of the texture of potato strips after blanching.


*Keywords:* Potato tuber; French fries; French fries processing line; Texture; Non-starch polysaccharide; Lignin

## 1. Introduction

French fries are the most popular potato products in many countries. They owe their popularity to eye-appealing golden colour, good flavour and aroma of the fried potato and characteristic texture (Lisińska & Leszczyński, 1989; Talburt & Smith, 1987). The texture of French fries is mainly dependent on the quality of the raw material, although technological parameters are also very important.

Until recently studies of French fries manufacturing have primarily focussed on the mechanisms affecting colour and the factors affecting flavour and aroma of the product. The results of extensive studies on the quality characteristics mentioned above allow the manufacturers of French fries to obtain a high quality product with no difficulty. However, the mechanisms influencing the texture of French fries have not been studied extensively and need further investigation. Non-starch-polysaccharides (NSP) and lignin are, in addition to starch, the main texture-affecting constituents of the potato (Andersson, Gekas, Lind, Oliveira, & Oste, 1994), and make up to one half of the non-starch dry matter content of the potato (Lisińska & Leszczyński, 1989). van Marle, Clerkx, and Boekenstein (1992), van Marle, Der Vuurst de Vries, Wilkinson, and Yuksel (1997a), Marle et al. (1997b) studied the cellular structure of cooked potatoes and found that the changes in texture resulted from the damaged middle lamella and cell walls as well as starch gelatinization.

There are few data in the literature on changes in NSP and lignin contents and composition of potatoes, on potato half- and finished products, during the entire technological process. In general, only one of the technological processes is investigated, e.g. peeling or blanching. For this reason, it is important to carry out studies that will allow us to determine which technological processes are

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responsible for the texture of the finished product. It is still not known whether particular chemical components of the potato confer the characteristic texture of French fries or what quantitative ratios of these should be sought in the potato varieties considered suitable for French fries manufacturing.

The purpose of the present study was to determine the changes in pectins, hemicelluloses, cellulose and lignin contents of potatoes at particular stages of French fries manufacturing and also the relationship between the texture of the finished product and that of half-products obtained during a particular stage of processing.

## 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 nine locations on a French fries processing line. Sample 1, consisted of potatoes before peeling; sample 2, steam-peeled potatoes (pressure 1,6 MPa time 0.5 min; sample 3, pre-cooked potatoes at 35 °C for 20 min; sample 4, potato strips (0.7×0.7 cm) by hydro-cutting; sample 5, potato strips after stage I of blanching at 72 °C for 5.0 min; sample 6, potato strips after stage II of blanching at 80 °C for 5.5 min; sample 7, pre-dried potato strips at 37 °C for 6.0 min; sample 8, French fries after stage I of frying at 180 °C for 45 s; sample 9, French fries after stage II of frying at 180 °C for 3 min. After stage I of frying, French fries were frozen at −27 °C.

### 2.2. Analysis

Immediately after the samples were collected from the processing line, the texture of potatoes was determined using an Instron 5544 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 the maximum shear force ($F_{max}$) necessary to cut the potato strips.

Pectins, cellulose, hemicelluloses and lignin contents were determined by the Dever, Bandurski, & Kiviliaan (1968) method, modified by Jaswal (1970) and Tajner-Czopek, Kita, & and Lisińska (1997) after freeze-drying of the potatoes.

### 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 ($P \leqslant 0.05$). The possible correlation between the potato texture and NSP and lignin contents in potato from particular stages of French fries processing line and also the relationship between French fries texture and potato texture from different stages of the French fries processing line were analyzed using analysis of variance (ANOVA). The differences at $P \leqslant 0.05$ were considered significant.

## 3. Results and discussion

Table 1 shows that NSP and lignin contents of dry matter of unpeeled potatoes were: 2.86% pectins, 2.56%, hemicelluloses, 2.71% cellulose and 2.83% lignin. After peeling, pectin and cellulose contents of potato tubers increased by 3.27% and 2.95%, respectively. Slight changes were found in the hemicelluloses content, while lignin content was about 20% lower. Kita (2002), Garrote, Silva, & Bertone (2000) reported quantitative changes in NSP and lignin during potato peeling. Kita (2002) found about 30% decrease in the sum of NSP and lignin in potato tubers after peeling them by a carboround method, while the highest losses were found in the cellulose fraction. In our studies, the potatoes were steam-peeled and the changes in polysaccharide content as compared to those measured in the raw material were

Table 1
Contents of pectins, hemicelluloses, cellulose and lignin in potato during French fries processing*

| Samples | [% d.m.] | | | |
|---|---|---|---|---|
| | Pectins | Hemicelluloses | Cellulose | Lignin |
| Un-peeled potato | 2.86a | 2.56a | 2.71a | 2.83c |
| Potato after peeling | 3.27b | 2.63a | 2.95b | 2.34ab |
| Potato after pre-heating | 3.13ab | 2.62a | 2.39a | 2.32ab |
| Potato after cutting | 3.29b | 2.46a | 2.98b | 2.12a |
| Strips after stage I of blanching | 3.98c | 3.59b | 5.89c | 2.40abc |
| Strips after stage II of blanching | 3.23b | 3.78b | 5.90c | 2.87c |
| Strips after drying | 3.19ab | 4.01b | 6.06cd | 2.60bc |
| French fries after stage I of frying | 3.34b | 4.23b | 6.39de | 2.79bc |
| French fries after stage II of frying | 3.48b | 4.41b | 6.46e | 2.78bc |

* Different letters (a,b,c) indicate significant differences in columns ($P \leqslant 0.05$).

less drastic (Camire, Violette, Dougherty, & McLaughlin, 1997). Garrote et al. (2000) studied the losses of potato constituents with regard to the peeling method and found that the content of non-soluble fibre substances was higher when the potatoes were steam-peeled than with the use of mechanical methods.

The next stage of French fries production is heating. When potato tubers are pre-heated at 28–40 °C for 30 min, the temperature of the inner part reaches about 15 °C. According to Andersson et al. (1994), heat treatment can influence the texture of the potato strips obtained at a later stage of processing. In the present study, heat treatment neither resulted in significant changes in polysaccharide content of potato tubers (Table 1) nor their texture (Fig 1). The shear force, after peeling and after heat treatment, was 36 N. Similar results were obtained by Laza, Scanlon, & Mazza (2001) who did not find any significant changes in mechanical properties of potato tubers heated in the temperature range 33–47 °C as compared to those unheated.

Hydro-cutting used in French fries production, did not have a significant impact on polysaccharide or lignin contents of potato strips (Table 1). However, the same process reduced the hardness of potato strips; the shear force necessary to cut the strips decreased from 36 to 31 N (Fig. 1). This was due to the fact that soluble as well as some non-soluble components (e.g. starch and protein) were partially washed out during potato peeling, as they "fell out" from the damaged (open) cells of the external layer of potato strips.

The technological processes, such as blanching, cooking and frying, cause irreversible changes in the cell walls of fruit and vegetables. Heat treatment of the plant tissue results in protein denaturation, enzyme inactivation and partial washing out of soluble chemical components from the raw material (Jeremiah, 1996). Mate, Quartaert, Meerdink, & van't Riet (1998) found that major changes in the texture of potatoes occurred during the first two minutes of blanching as a result of loosening of the tissue structure. Further heat treatment only slightly affected the texture of the product. According to Andersson et al. (1994), softening of the tissue structure during heat treatment is, among others, likely due to starch pasting. Due to thermal treatment, pectic material is converted as a result of chemical degradation and activation of pectin esterase. On heating, chemical degradation of the pectin chain in potato tissue takes place according to the β-eliminative mechanism (Jarvis, Mackenzie, & Duncan, 1992; Keijbets, 1974). The results of the studies show that potato strips are softer after blanching and pre-drying (25 N) than after cutting (31 N) (Fig. 1). Further increase in softness was observed after stage I of frying (10 N). The shear force after stage II was 13 N. The increased hardness of the finished product, as compared to the half-product, resulted from the occurrence of the crispy surface on the French fries during the final stage of frying.

In our experiment, blanching resulted in significant changes in the content of NSP fractions of potatoes (Table 1). Potato strips, after stage I of blanching, contained much more cellulose (5.89%), hemicelluloses (3.59%) and pectins (3.98%) than potatoes at earlier stages of processing. Stage II of blanching reduced the pectin content of potato strips to 3.23%. No significant changes in pectins and cellulose content were found in the potatoes after further stages of processing. Cellulose content was the highest in French fries after frying stages I and II – 6.42%, on average. Among NSP fractions under investigation, the content of cellulose was the highest, similarly to our earlier studies (Golubowska & Lisińska, 2003). Such a high percentage of cellulose present in the dry substance of French fries was likely

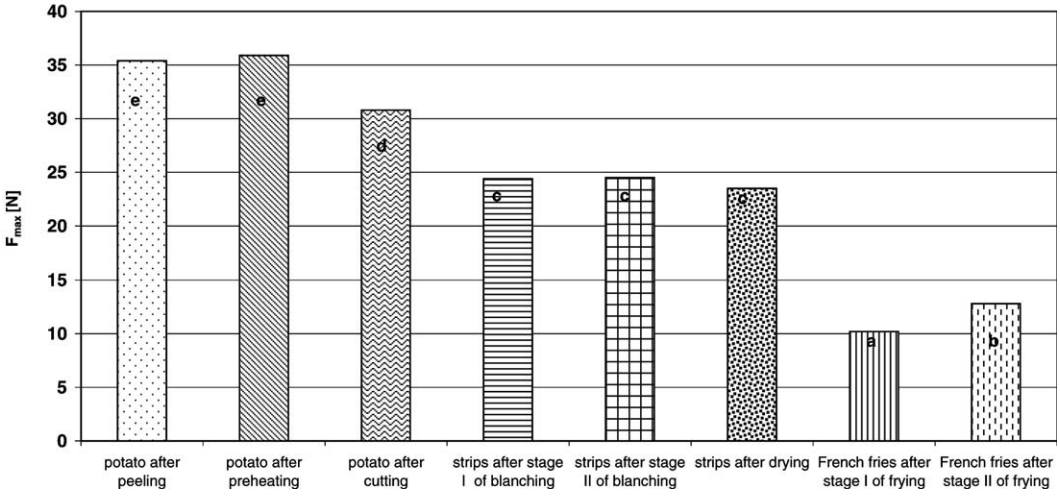


Fig. 1. Changes in potato texture [N] during French fries processing. Different letters indicate significant differences.

due to the wash out of the soluble fractions during processing. Another reason could also be the formation of resistant starch.

Changes in lignin content during French fries production were slight (Table 1). The lowest content of lignin (2.15% on average) was found in potatoes after peeling, pre-heating and cutting of the potato tubers. This was likely due to the higher lignin content of potato skin and outer layers of the potato, which are removed during peeling and after visual inspection. After blanching and frying, when soluble components were washed out, lignin content of potatoes increased, so that dry matter of the finished product contained 2.87% of lignin.

According to Asp (1996) an increase in non-starch polysaccharides of potatoes during heat treatment is likely due to the losses of non-fibre substances. Thed & Phillips (1995) report that potatoes cooked in a microwave or fried in oil have higher contents of NSP and lignin, while cooking and baking decrease the contents of theses components in potato tubers. Herranz, Vidal-Valverde, & Rojas-Hidalgo (1983) found that cooking of carrots, cabbage and broccoli increased cellulose content in these vegetables, but decreased hemicelluloses and lignin contents. However, these changes depend on the way of cooking.

Blanching, pre-drying and frying during French fries production cause the occurrence of a ''skeleton'' in the potato tissue consisting of various proportions of carbohydrate compounds influencing the texture of the finished product. A correlation coefficient between texture (N) and NSP and lignin contents was determined in order to find which component of the ''skeleton'' had the greatest impact on the texture (Table 2). The texture of the potatoes at each stage of processing was most frequently dependent on total pectin and cellulose contents. No correlation was found between the texture and the fractions under investigation in potato strips after stage II of blanching and pre-drying. Significant correlation coefficients between the texture and pectin ($r = 0.63$) and cellulose ($r = 0.84$) contents of French fries led us to conclude that these compounds have the greatest impact on texture of the finished product.

Statistical analysis of the data obtained in the study (Table 3) shows that the texture of potato strips after stages I and II of blanching is correlated with the texture of French fries after frying at $r = 0.72$ and $r = 0.54$, respectively. The high correlation coefficient may, therefore allow us to predict the texture of a half-product as soon as blanching processes are done. The results obtained in the study suggest that potato strips exhibiting a shear force of 25 N after stage I of blanching are likely to give a good quality finished product provided that adequate parameters are maintained during pre-drying and frying processes.

Table 2
Correlation coefficient between potato texture [N] and contents of NSP and lignin in potato tubers from particular stages of French fries processing line

| Samples | Correlation coefficient [$r$] | | | |
|---|---|---|---|---|
| | Pectins | Hemicelluloses | Cellulose | Lignin |
| Potato after peeling | 0.77* | 0.57 | 0.70* | 0.06 |
| Potato after pre-heating | 0.68* | 0.83* | 0.75* | 0.11 |
| Potato after cutting | 0.61* | 0.43 | 0.62* | −0.65* |
| Strips after stage I of blanching | 0.21 | 0.07 | 0.22 | 0.65* |
| Strips after stage II of blanching | 0.31 | 0.28 | 0.27 | −0.35 |
| Strips after drying | 0.13 | 0.14 | 0.09 | −0.16 |
| French fries after stage I of frying | 0.86* | 0.78* | 0.23 | −0.68* |
| French fries after stage II of frying | 0.63* | 0.46 | 0.84* | 0.10 |

* Significant correlation.

Table 3
Correlation coefficient between texture [N] of potato at different stages of processing and texture of French fries after stages I and II of frying

| Samples | Correlation coefficient [$r$] | |
|---|---|---|
| | French fries after stage I of frying | French fries after stage II of frying |
| Non-peeled potato | 0.43 | 0.27 |
| Potato after pre-heating | 0.40 | 0.34 |
| Potato after cutting | 0.44 | 0.42 |
| Strips after stage I of blanching | 0.24 | 0.72* |
| Strips after stage II of blanching | 0.58* | 0.54* |
| Strips after drying | 0.48 | 0.17 |

* Significant correlation.

## 4. Conclusions

The data obtained in the study show that blanching and frying are the processes that have the greatest impact on the changes in NSP and lignin contents as well as the texture of potatoes. Pectins and cellulose proved to be the substances having the greatest influence on the texture of French fries. The texture of French fries can be predicted from the measurements of the texture of potato strips after blanching.

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## References

Andersson, A., Gekas, V., Lind, I., Oliveira, F., & Oste, R. (1994). Effect of preheating on potato texture. *Critical Reviews in Food Science and Nutrition, 34*, 229–251.

Asp, N. G. (1996). Dietary carbohydrates classification by chemistry and physiology. *Food Chemistry, 57*, 9–14.

Camire, M. E., Violette, D., Dougherty, M. P., & McLaughlin, M. A. (1997). Potato peel dietary fiber composition: Effects of peeling and extrusion cooking processes. *Journal of Agricultural and Food Chemistry, 45*, 1404–1408.

Dever, J. E., Bandurski, R. S., & Kiviliaan, A. (1968). Partial chemical characterization of corn root cell walls. *Plant Physiology, 43*, 50–56.

Garrote, R. L., Silva, R. E., & Bertone, R. A. (2000). Effect of thermal treatment on steam peeled potatoes. *Journal of Food Engineering, 45*, 67–76.

Gołubowska, G., & Lisińska, G. (2003). Changes in contents of non-starch polysaccharides and lignin in potato tubers during the French fries processing. *Żywność, Nauka, Technologia, Jakość, 1*(34), 91–98 (In polish).

Herranz, J., Vidal-Valverde & Rojas-Hidalgo, E. (1983). Cellulose, hemicelluloses and lignin content of raw and cooked processed vegetables. *Journal of Food Science, 48*, 247–276.

Jarvis, M. C., Mackenzie, E., & Duncan, H. J. (1992). The textural analysis of cooked potato. *Potato Research, 35*, 93–102.

Jaswal, A. S. (1970). Non-starch polysaccharides and the texture of French fried potato. *American Potato Journal, 47*, 311–316.

Jeremiah, L. E. (1996). *Freezing effects on food quality*. New York, Basel, Hong Kong: Marcel Dekker, Inc..

Keijbets, M. J. H. (1974). *Pectic substances in the cell wall and the intercellular cohesion of potato tuber tissue during cooking*. Wageningen, The Netherlands: Pudoc.

Kita, A. (2002). The influence of potato chemical composition on crisp texture. *Food Chemistry, 76*, 173–179.

Laza, M., Scanlon, M. G., & Mazza, G. (2001). The effect of tuber preheating temperature and storage time on the mechanical properties of potatoes. *International Food Research, 34*, 659–667.

Lisińska, G., & Leszczyński, W. (1989). *Potato science and technology*. London, New York: Elsevier Applied Science.

van Marle, J. T., Clerkx, A. C. M., & Boekenstein, A. (1992). Cryo-scanning electron microscopy investigation on the texture of cooked potatoes. *Food Structural, 11*, 209–216.

van Marle, J. T., Der Vuurst de Vries, R., Wilkinson, E. C., & Yuksel, D. (1997a). Sensory evaluation of the texture of steam-cooked table potatoes. *Potato Research, 40*, 79–90.

van Marle, J. T., Stolle-Smits, T., Donkers, J., van Dijk, C., Voragen, A. G. J., & Recourt, K. (1997b). Chemical and microskopic charakterization of potato (Solanum tuberosum L.) cell walls during cooking. *Journal of Agricultural and Food Chemistry, 45*, 50–58.

Mate, J. I., Quartaert, C., Meerdink, G., & van't Riet, K. (1998). Effect of blanching on structural quality of dried potato slices. *Journal of Agricultural and Food Chemistry, 46*, 676–681.

Tajner-Czopek, A., Kita, A., and Lisińska, G. (1997). Determination of non-starch polysccaride in potato tubers. (in polish) XXVIII Scientific Session Materials "The progress in food technology and chemistry", Gdańsk, 270–271.

Talburt, W.F., and Smith, O. (1987). Potato processing. (4 ed.). *AVI Van Nostrand Reinhold Com*. New York.

Thed, S. T., & Phillips, R. D. (1995). Changes of dietary fiber and starch composition of processed potato products during domestic cooking. *Food Chemistry, 52*, 301–307.