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EFFECT OF POTATO STRIPS PRE-DRYING METHODS ON FRENCH FRIES QUALITY

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Key words: quality, French fries, pre-drying, vacuum-microwave, convection

The aim of the work was to estimate the effect of microwave and convective dehydratation parameters of potato strips after blanching on French fries quality. After washing and peeling, potato tubers were cut into strips, which underwent one-stage blanching in water (for 10 min at 75°C). After blanching the potato strips (10x10 mm) were dried with two methods: vacuum-microwave at two levels of magnetrons power (360 W and 480 W) and by changing pressure at the range from 4 kPa to 6 kPa, and convective pre-drying performed at 50°C and 75°C at constant air speed of 2m/s. The control samples were made of blanched, not pre-dried potato strips. After potato strips pre-drying the French fries were prepared with the two-stage frying method in canola oil. French fries were subjected to sensory evaluation. Their fat content, colour and texture were determined with instrumental methods. The texture of French fries was estimated in two tests: cutting and bending. Changes in the structure of potato tissue were determined using a scanning electron microscope.

It was stated that the pre-drying time in the vacuum microwave method was about four-times shorter than that in the convective method. French fries made of strips pre-dried with the vacuum microwave method absorbed less fat (by about 9% on average), than those pre-dried with the convective method. Pre-drying of potato strips lowered the fat content in the finished product by 28% compared with the non-pre-dried control samples The smaller cutting force and bending strength were exhibited byFrench fries made of potato strips pre-dried with the convective pre-drying method at 75°C and 50°C compared with the microwave method. Based on the sensory and instrumental results, it was found that French fries pre-dried with the vacuum microwave method were characterised by better quality attributes, as compared with French fries pre-dried with the convective method and control samples without pre-drying.

INTRODUCTION

Basic quality characteristics of fries include: colour, taste, odour, texture and fat content [Talburt & Smith, 1987; Lisińska & Leszczyński, 1989]. They affect the attractiveness of the ready product to a substantial extent. Nowadays, production of French fries with the desired colour, taste and odour constitutes no problem to the producers, the attention being directed to obtaining proper texture and fat content.

Colour is one of the appearance attributes of food materials, since it influences consumer acceptability [Maskan, 2001]. It is desirable that French fries be of a light, golden colour without any brown overcolouring or black spots and traces [Lisińska & Leszczyński, 1989].

The next quality feature is fat content. The content of fat in fries depends first of all on dry matter and starch content in the potatoes, though it is also connected with the kind of oil used for frying and technological factors, such as thickness of the strips, kind of blanching, temperature and time of initial drying of potato chips [Lisińska & Leszczyński, 1989] and frying parameters [Saguy *et al*., 1998].Consumer preference for low-fat and fat-free products has been the driving force of this food industry to produce fried potatoes with a reduced content of oil that still retain the desirable flavour and texture [Pedreschi & Moyano, 2005].

A quality feature that, to a large extent, determines consumer acceptability of food products is texture. It is described as a complex determined by structure, shape, chemical composition, viscosity and other physical properties of the final product [Szczesniak-Surmacka, 2002]. French fries texture is of critical importance to consumer acceptability [Agblor & Scanlon, 2000]. French fries of advantageous texture are delicate, with crispy skin and floury interior [Tajner-Czopek *et al*., 2003; Lisińska & Leszczyński, 1989]. Two notions contribute to French fries texture: external texture – crispness and internal texture – mealiness of their interior. The external layer of French fries should not be hard, leathery or gummy, whereas the interior part should be mealy without any impression of being watery or mushy and there should be no separation between core and crust [Lisińska & Leszczyński, 1989; Talburt & Smith, 1987]. The texture of French fries can be determined on the basis of sensory estimation as well as with the use of objective (instrumental) methods using Stevens QTS or Instron [Bourne, 2002].

French fries consistence depends on technological processes applied during production, such as blanching, pre-drying, pre-frying, and frying [Agblor & Scanlon, 2000].

Blanching is a one of the technological stages of French fries production [Agblor & Scanlon, 2000]. A proper choice

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of parameters for that stage enables obtaining good quality products, as well as improvement of those properties of French fries that do not meet the norm [Lisińska & Leszczyński, 1989]. Properly chosen parameters of blanching of potato strips result in uniform colour of the French fries, induce surface gelatinization of starch (the adsorption of fat is then reduced and time of frying shortened) and improve texture of the ready product.

Proper selection of blanching and frying parameters is essential for the quality attributes of French fries. A process that can also improve the sensory traits of French fries is pre-drying of potato strips after blanching. The pre-drying before frying has the following advantages: it is very easy to maintain uniform colour of the product during and after the frying, product stability is optimal, weak and soggy product is not obtained after the frying process, the oven-ready product stays crispy and the pre-dried product absorbs much less fat during frying [Lisińska & Leszczyński, 1989].

There are various methods of drying and pre-drying used in the food industry, *e.g.* convective, vacuum microwave or convection-microwave. Among them the microwave drying enable warming up the material in all mass, which is a major advantage over the conventional methods [Jones, 1992]. Microwave drying is also rapid, more uniform and energy efficient compared to conventional hot air drying. In order to prevent significant losses of nutrients, flavor and color, microwave drying is successfully used instead [Drouzas & Schubert, 1996].

It is thought that the microwave pre-drying methods may affect the quality of French fries to a considerably greater extent than the conventional methods. Especially lowering fat content, preservation of proper colour and texture of fries will speak in favour of applying the microwave method for pre-drying potato chips. The aim of the work was to estimate the effect of microwave and convective dehydratation parameters of potato strips after blanching on finished product quality.

MATERIALS AND METHODS

Materials. The raw material investigated were potato tubers designed for French fries preparation, purchased from the producer's factory near Wrocław (Poland). The potato tubers were characterised by proper chemical composition and reducing sugars contents.

Analysis. The raw material was determined for dry matter by drying method at a temperature of 105°C [AOAC, 1995]. After washing and peeling the tubers were cut into potato strips, which underwent one-stage blanching (for 10 min at 75°C). After blanching, the potato strips (10x10 mm) were dried with vacuum-microwave and convective methods. Microwave pre-drying was carried out with an SM-200 Plazmatrinika drier under lowered pressure at two levels of magnetrons power (360W and 480W) with the pressure changing in the range of 4 to 6 kPa. The convective pre-drying was conducted using a drying equipment made at the Institute of Agricultural Engineering, that enabled simultaneous drying of 6 batches of material. The convective drying was performed at 50°C and 75°C with constant air speed of 2 m/s. The control samples constituted blanched, not pre-dried potato strips. The potato strips pre-dried with two methods and for French fries were assayed for dry matter with the method of drying to constant dry matter at 105°C [AOAC, 1995]. In the French fries investigated the content of fat was determined with the Soxhlet method, which involved extraction with diethyl ether in a Büchi Distillation Unit B-316 device [AOAC, 1995].

The French fries were prepared by the two-stage frying method in canola oil. After 5-min frying the texture was determined with the use of Instron Model 5544 Universal Texture Analyser provided with the cutting attachment QTS-25-SB "Share blade". The cutting attachment was moving at the speed of 250 mm/min and the extensometer head in a range up to 2000 N. Fifteen French fries were taken to repeated laboratory measurements. Cutting all the samples took place in the middle of their length. From the plots the cutting force (*Ft*) *versus* knife displacement (ΔL) the maximum cutting force Ft_{max} (N) was determined (Figure 1).

The samples analysed were subjected to a bending test. In a three-point bending test the attachment was moving at the speed of 5 mm/min and the extensometer head in a range up to 2000 N. In the bending test the maximum bending stress $\sigma_{g_{max}}$ was found from the relation:

$$\sigma_{g_{max}} = Mg_{max}/W_x \quad (1)$$

where:
$$Mg_{max} = 0.25 \cdot F_{g_{max}} \cdot l \quad (2)$$

$F_{g_{max}}$ – maximum bending force

l – distance between supporting points

W_x – bending strength index

$$W_x = a^3/6 \quad (3)$$

a – length of potato strip cross-section side.

The colour of French fries was measured with the use of a Minolta Chroma Meter CR-200 system. The difference in colour of the samples was determined on the basis of a mea-

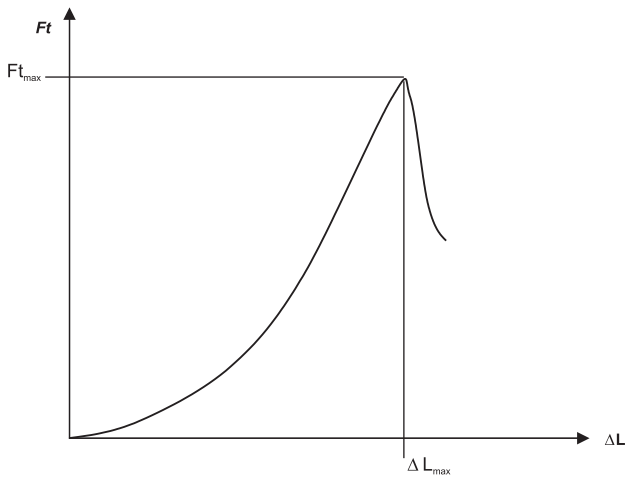

FIGURE 1. Determination of the maximum cutting force Ft_{max} (N).

surement in the CIE system at *L, a* and *b* configuration. The colour values were expressed as *L* (whiteness or brightness/darkness – represents spectrum with a range from 0 (black) to 100 (white), *a* (redness/greenness) and *b* (yellowness/blueness).

An organoleptic assessment of the French fries was also carried out according to a 5-point scale (1 point – the worst, 5 points – the best), allowing for the evaluation of thefollowing quality attributes: colour, flavor, odor and texture.

Changes in the structure of potato tissue were determined in potato strips before and after pre-drying with microwave and convective methods, using a Leo-435VP scanning electron microscope (SEM). The samples for SEM were fixed immediately after handling, by freezing in liquid nitrogen and spraying with gold.

Statistical analysis. The results were analysed statistically using a Statistica 7.0 software (2005). For comparison, the results obtained were analysed using one-way analysis of variance with the application of Duncan's test ($p \leq 0.05$). To assess the ranks of the variables (organoleptic evaluation of French fries on the 1-5 scale), the non-parametric Kruskal-Wallis test was used. Homogenous groups were formed on the basis of the ranks determined.

RESULTS AND DISCUSSION

Dry matter changes

The kinetics of potato strips pre-drying was described with an exponential function in the variables of dry matter of potato strips (DM) – time (t) (Figure 2).

$$DM = 14.99 + 4.4 \cdot (1 - e^{\frac{\tau}{4.46}}),\ R^2 = 0.997\ (N = 480W) \quad (4)$$

$$DM = 12.12 + 7.21 \cdot (1 - e^{\frac{\tau}{9.37}}),\ R^2 = 0.999\ (N = 360W) \quad (5)$$

$$DM = 19.4 + 22.81 \cdot (1 - e^{-\frac{\tau}{42.45}}),\ R^2 = 0.987\ (t = 75°C) \quad (6)$$

$$DM = 19.4 + 7.58 \cdot (1 - e^{-\frac{\tau}{19.92}}),\ r^2 = 0.983\ (t = 50°C) \quad (7)$$

The drying rate curves described in Figure 3 are derivatives of the drying kinetics curve (Figure 2).The course of the functions found indicated that a decrease in the drying rate should be expected when pre-drying potato strips with the convective method, whereas with the microwave heating an increase in the pre-drying rate was observed (Figure 3). As reported by Jones [1992], during microwave drying the material warms up in bulk, which increases the rate of water evaporation; whereas major disadvantages of the hot air drying of foods are low energy efficiency and lengthy drying time in the falling rate period [Maskan, 2000]. Lisińska & Gołubowska [2005] report that the content of dry matter in the strips after pre-drying proves to be of about 25%. Based on the results presented it can be stated that the pre-drying of potato strips with the convective method at the temperature of 75°C can

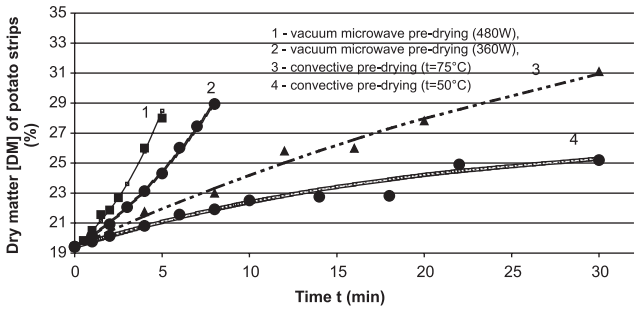

FIGURE 2. The kinetics of pre-drying potato strips with the vacuum microwave method: 1- (480W) and 2- (360W) and convection method: 3 (t=75˚C), 4 (t=50˚C).

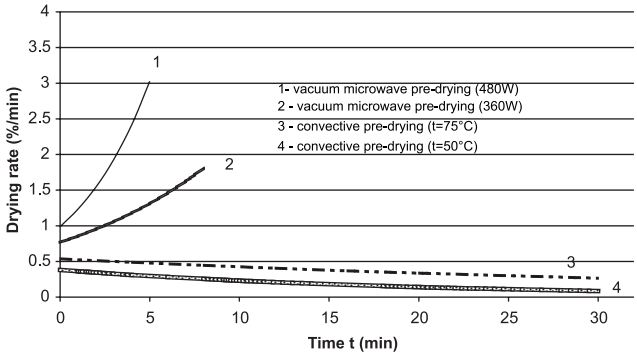

FIGURE 3. Drying rate curves of potato strips under various pre-drying methods.

yield such dry matter content to 25 min, whereas with the convective method at the temperature of 50°C – about 12.5 min, and with the vacuum microwave method that time is four times shorter on average.

Fat uptake

The pre-drying of potatoes before frying using microwave, hot-air treatment and baking has resulted in a significant reduction in oil content of French fries [Moyano *et al*., 2002; Krokida *et al*., 2001; Lamberg *et al*., 1990]. The content of fat in fries is an important factor of their characteristics. Too much fat content in a fried product endows it with an oily taste, while too little fat content deprives it of the typical taste and odour of the fried product. It is assumed that French fries after the first stage of frying should contain up to 4% of fat, whereas the finished product up to 7% [Lisińska & Leszczyński, 1989].

On the basis of the investigations performed it can be stated that fat content in French fries was connected with application of pre-drying and the applied method of pre-drying the potato strips after blanching (Figure 4). It was found that fat content of French fries made of strips that were not pre-dried was about 12.79%, whereas that of French fries made of pre-drying potato strips was (on average) by 28% lower. The lowest fat content had fries pre-dried with the vacuum microwave method at 480W power. French fries made of strips pre-dried with the vacuum microwave method absorbed, on average, about 9% less fat than those pre-dried with the convective method.

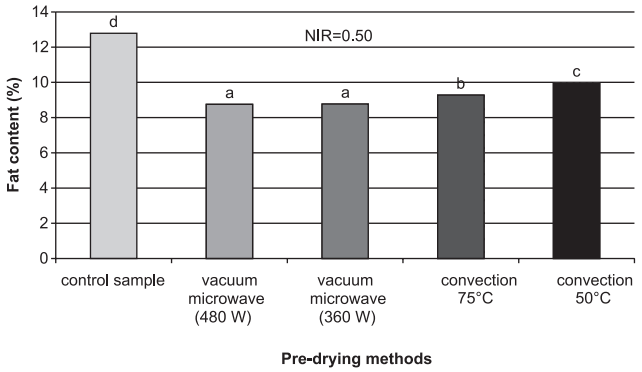

FIGURE 4. Fat content of French fries as dependent on the method of pre-drying the potato strips (different letters (a,b,c,d) indicate significant differences of results (p≤0.05)).

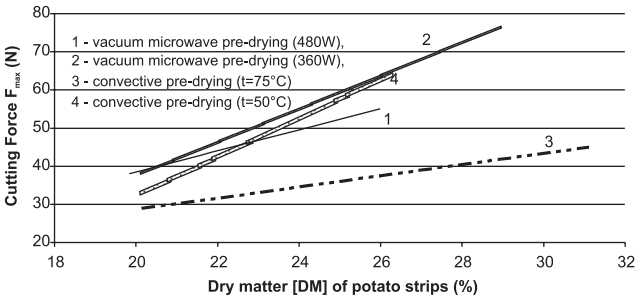

FIGURE 5. Values of the maximum cutting force (Ft_{max}) of French fries as dependent on the pre-drying methods of potato strips.

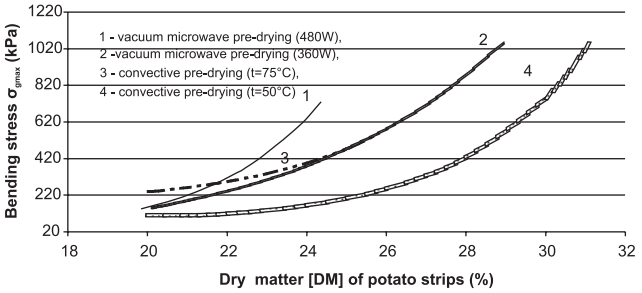

FIGURE 6. Values of the maximum bending stress ($\sigma_{g\,max}$) of French fries as dependent on the pre-drying methods of potato strips.

Texture measurements

On the basis of the investigations performed it was found that the maximum cutting force needed to cut the French fries obtained from potato strips increased with increasing dry matter content of the strips (Figure 5) and proportionally increased the maximum bending stress (Figure 6). With increasing dry matter of potato strips the resulting French fries were characterised by increasing hardness. With increasing dry matter of potato strips the dry matter of French fries was increasing too (data not presented), then the resulting French fries were characterised by increasing hardness.

It was also found that the smallest cutting force and strength to bending showed French fries made of potato strips that were pre-dried with the convective method at a temperature of 75°C (the samples analysed exhibited soft consistency). Lowering the drying agent temperature from 75°C to 50°C caused increased strength of the French fries, making it comparable to the strength of microwave pre-dried fries and thus improving consistency of the finished product.

Colour measurements

The results of the colour parameters obtained from different pre-drying processes are presented in Figure 7-9 for *L*-, *a*-, *b*-values, respectively. The values of the colour

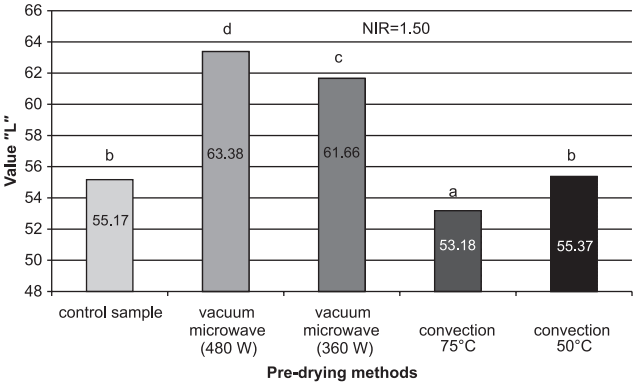

FIGURE 7. French fries colour (*L* – mean value) as dependent on the pre-drying methods (different letters (a,b,c,d) indicate significant differences of results (p≤0.05)).

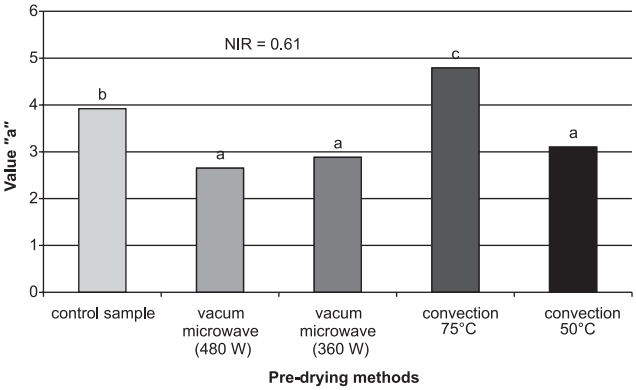

FIGURE 8. French fries colour (*a* – mean value) as dependent on the pre-drying methods (different letters (a,b,c) indicate significant differences of results (p≤0.05)).

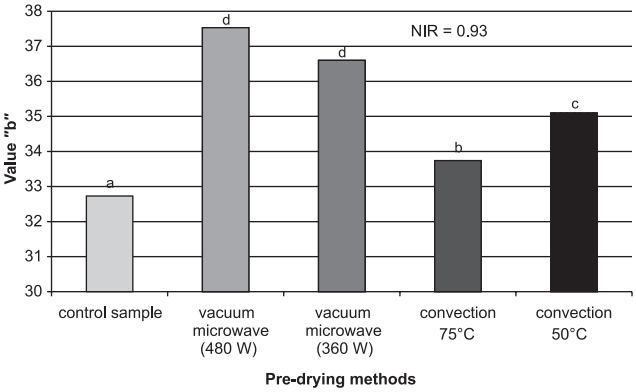

FIGURE 9. French fries colour (*b* – mean value) as dependent on the pre-drying methods (different letters (a,b,c,d) indicate significant differences of results (p≤0.05)).

index varied in the range from 63.38 to 55.17 (Figure 7), those of the index *a* – from +4.79 to + 2.65 (Figure 8), whereas those of index *b* from 37.53 to 32.73 (Figure 9). The results presented in this work suggest that the changes in *L, a,* and *b* values were small. Based on the obtained *L, a* and *b* indices, it can be stated that the best (bright) colour was characteristic of French fries obtained from potato strips pre-dried with the vacuum microwave method at 480W, while the least appropriate (dark colour) was that of French fries made of strips that were pre-dried with the convective method (at 75˚C) and the control sample that was left without pre-drying. The indices were, however, not disqualifying the French fries with respect to colour. Feng & Tang [1998] found that vacuum microwave pre-drying caused little and hot air drying exhibited the greatest reduction in the colour of sliced apples. Maskan [2000] reported that microwave drying caused less change in colour in fresh bananas compared to hot air drying method. This author reports that drying time plays an essential role in color formation. With increasing drying temperature and time the color of the dried product becomes darker. Fruits and vegetables are well suited for drying with the microwave method due to their large water content that efficiently absorbs the microwave power. However, the time of drying should be short if one wants to obtain good quality dried product, *e.g.* bananas [Drouzas *et al*., 1999; Drouzas & Schubert, 1996] and potatoes [Bouraout *et al*., 1994].

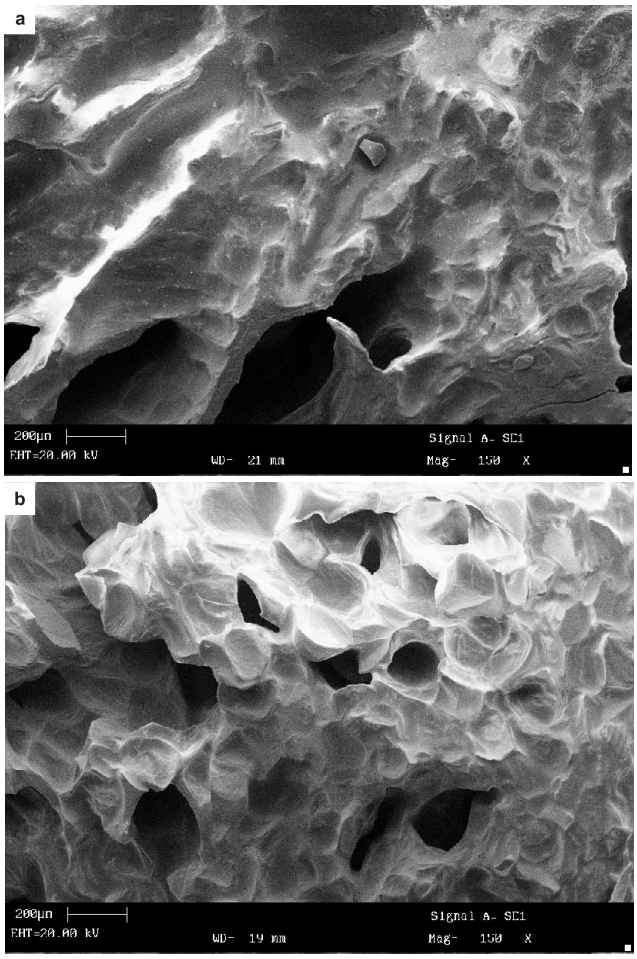

FIGURE 10. SEM pictures of French fries pre-dried with (a) vacuum microwave pre-drying method and (b) convective pre-drying method.

Sensory assessment

Appearance analyses of foods (colour, taste, odour and texture) are used in maintenance of food quality throughout and at the end of processing [Maskan, 2001]. Sensory evaluation of the vacuum microwave pre-dried, convection predriedand control samples (without pre-drying) of French fries was carried out to obtain preliminary information on consumer preference. Based on the results of a sensory evaluation (in a 5-point scale) of French fries made of strips pre-dried with various methods, significant differences were found between French fries pre-dried with microwaves, convection, and the control sample (Table 1).

The pre-drying methods did considerably affect the taste, colour and texture of the French fries. Better colour and texture, in comparison to convectional pre-drying and control samples, showed the French fries obtained from potato strips that were pre-dried with the vacuum microwave method, and they were assigned the score of over 4.5 points. As the power of the magnetrones of the vacuum microwave method increases (from 360 W to 480W), the French fries become of better quality. As the temperature of the convective pre-drying increased (from 50°C to 75°C) the French fries became harder (texture) and with worse colour. The taste of the analysed samples was better after vacuum microwave pre-drying to compare with convection pre-drying. The odour of French fries was not dependent on pre-drying methods of potato strips.

High temperature and long drying times, required to remove water from the sugar containing raw material in convective air drying, may cause serious damage to the flavour, colour, nutrients, reduction in bulk density and rehydratation capacity of the dried product [Drouzas *et al*., 1999]. Drouzas & Schubert [1996] reported that vacuum microwave drying is known to result in a poor quality product if not properly applied.

SEM pictures

Figure 10a shows the cross-section of potato strips after vacuum microwave pre-drying and Figure 10b shows the cross-section of potato strips after convection pre-drying. It was stated that the structure of potato tissue after vacuum microwaves pre-drying was more concise, than after convection pre-drying. Therefore the French fries obtained from potato strips after vacuum microwaves pre-drying absorb less fat as compared to ready product after convection pre-drying.

CONCLUSIONS

The kinetics of pre-drying the potato strips with the convection and vacuum microwave methods could be described by an exponential function. The pre-drying time to obtain a definite dry mass content (*ca*. 25%) in the vacuum microwave method was about four times shorter than that in the convection method.

French fries made of strips pre-dried with the vacuum microwave method absorbed less fat by about 9% (on average), than those pre-dried with the convection method. Pre-drying

TABLE 1. Sensory attributes of French fries as dependent on the method of pre-drying potato strips.

Methods of pre-drying	Colour (points 1-5)	Taste (points 1-5)	Odour (points 1-5)	Texture (points 1-5)	Mean value (points 1-5)
1	4.50^{eB}	4.50^{cB}	4.25^{aA}	5.00^{dC}	4.56^{d}
2	4.25^{dA}	4.50^{cB}	4.25^{aA}	4.25^{cA}	4.31^{d}
3	3.00^{aA}	3.50^{aB}	4.25^{aC}	3.50^{aB}	3.55^{a}
4	3.75^{cA}	4.25^{bB}	4.25^{aB}	3.75^{bA}	4.00^{c}
Cs	3.50^{bA}	3.50^{aA}	4.25^{aC}	3.75^{bB}	3.75^{b}

1 – vacuum microwave pre-drying (480 W); 2 – vacuum microwave pre-drying (360 W);
3 – convection pre-drying 75°C, 4 – convection pre-drying 50°C; CS – control samples (without pre-drying); lower-case letters indicate significant differences in columns ($\alpha \leq 0.05$); capital letters indicate significant differences between columns ($\alpha \leq 0.05$); * mean values of 5 replications

of potato strips lowered fat content of the finished product by 28% as compared with non-pre-dried control samples.

The smaller cutting force and bending strength exhibited French fries made of potato strips pre-dried with the convective pre-drying method at 75°C and 50°C as compared with the microwave method.

Based on the organoleptic and instrumental results, it was found that French fries pre-dried with the vacuum microwave method were characterised by better quality attributes, compared with French fries pre-dried with the convection method and control samples without pre-drying.

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WPŁYW METODY PODSUSZANIA KRAJANKI ZIEMNIACZANEJ NA JAKOŚĆ FRYTEK

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Celem badań było określenie wpływu parametrów podsuszania metodą mikrofalową i konwekcji, krajanki ziemniaczanej po blanszowaniu na jakość frytek. Z prób ziemniaków po umyciu i obraniu przygotowano krajankę ziemniaczaną, którą poddano jednostopniowemu blanszowaniu w wodzie w 75°C przez 10 minut. Po blanszowaniu słupki ziemniaka (10x10 mm) podsuszano dwiema metodami: mikrofalową w warunkach obniżonego ciśnienia, przy dwóch poziomach mocy magnetronów (360W i 480W) i ciśnieniu zmieniającym się w zakresie od 4kPa do 6kPa oraz podsuszanie metodą konwekcji wymuszonej przeprowadzono w temperaturze 50°C i 75°C, przy stałej prędkości przepływu powietrza suszącego – 2m/s. Próbę kontrolną stanowiła krajanka blanszowana, niepodsuszona. Z podsuszonej krajanki sporządzono frytki metodą dwustopniowego smażenia w oleju rzepakowym. Frytki poddane zostały ocenie sensorycznej. Zawartość tłuszczu, barwę i konsystencję oznaczono obiektywnymi metodami. Konsystencję frytek określono na podstawie dwóch testów: przecinania i zginania. Zmiany w strukturze tkanki ziemniaka określono przy użyciu mikroskopu elektronowego. Stwierdzono, że czas podsuszania z zastosowaniem metody mikrofalowej był około czterokrotnie krótszy, niż czas podsuszania z zastosowaniem metody konwekcyjnej.

Frytki sporządzane z krajanki podsuszanej metodą mikrofalową chłonęły średnio o około 9% mniej tłuszczu w porównaniu z podsuszaniem metodą konwekcyjną. Podsuszanie metodami mikrofalowymi i konwekcyjnymi obniżyło zawartość tłuszczu we frytkach średnio o około 28% w porównaniu z próbą kontrolną (niepodsuszona). Mniejszą wytrzymałością na przecinanie i zginanie charakteryzowały się frytki sporządzone z krajanki podsuszanej metodą konwekcyjną w temperaturze 50°C, w porównaniu z podsuszaniem w temp. 75°C i metodami mikrofalowymi. Na podstawie wyników oceny organoleptycznej i instrumentalnej stwierdzono, że frytki podsuszane metodą mikrofalową charakteryzowały się korzystniejszymi wyróżnikami jakościowymi w porównaniu z frytkami podsuszanymi metodą konwekcyjną i próbami kontrolnymi, uzyskały one wyższe oceny.