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Effect of lovage phenolics to formation of acrylamide in French fries

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Abstract. One of the novel methods for reduction of acrylamide in food is application of plant phenolics in technological process of Latvian plants as lovage contain significant amounts of plant phenolics and other natural antioxidants. The aim of current research was to determine the effect of lovage extracts to the formation of acrylamide in French fries. Variety 'Lenora' potatoes were used. Potatoes were sliced and blanched in hot water (85 ± 2 °C 8 min). After blanching samples were treated with lovage water and ethanol extracts and four samples were obtained: control (without additional treatment); SW – sprayed with water extract, IMW – immersed in water extract, SE sprayed with ethanol extract. After treatment all samples were fried in oil (180 ± 2 °C) for 7 minutes. Total phenolic (TPC), vitamin C content and antioxidant activity (DPPH and ABTS) were determined for all samples before and after frying. For fried potatoes acrylamide and breaking force with texture analyser were determined. TPC of samples during frying decreased significantly but comparing fried samples the highest TPC in SE sample was determined. The highest DPPH radical scavenging activity was observed in samples treated with water extract but during frying the DPPH activity for all treated samples was lower than to control sample. The most significant changes in ABTS radical scavenging activity were observed and also the highest activity of sample SE was observed. Vitamin C content decreased significantly during frying, the highest vitamin C content in SE sample was determined. The highest maximal breaking force of fried potatoes was detected for sample IMW, but the lowest for sample SE. The lowest acrylamide content was found in sample, which was sprayed with lovage-water extract.

Key words: French fries, lovage, treatment, ABTS, ascorbic acid, breaking force.

INTRODUCTION

Potatoes are the fourth-most-consumed food crop in the world, after rice, wheat, and corn. The most popular potato products are French fries, chips, and dried potato products. Frozen French fries are the top U.S. potato product export, accounting for more than half of total potato export volume. In 2009, exports of frozen French fries totalled 3.0 billion pounds (fresh-weight-equivalent basis), valued at $635 million. Canada is the largest supplier, followed distantly by Mexico, the Netherlands, and Germany (USDA, 2014).

Potato products such as French fries and chips contains high levels of acrylamide that forms during thermal treatment in reaction between sugars and asparagine.

Acrylamide is a substance that is produced naturally in foods as a result of high-temperature cooking, e.g., baking, grilling, or frying (Mottram et al., 2002).Average daily intake levels of this Maillard reaction product are estimated to be 0.3–0.7 μg acrylamide kg^{-1} day^{-1} (Dybing et al., 2005).

Potatoes are rich in both asparagine and glucose. Asparagine is the free amino acid presented in high amounts in potatoes (93.9 mg 100 g^{-1}) (Martin & Ames, 2001).

Due to urotoxic, genotoxic and probable carcinogenic properties of acrylamide several methods are developed to reduce its content in different food matrixes such as prevention of reducing sugar liberation during the storage period of food materials (Fiselier & Grob, 2005), change of heat processing methods (Granda et al., 2004), selection of suitable cultivar and storage temperature of food materials (Grob et al., 2003; Rommens et al., 2008), modification of pH (Jung et al., 2003) reduction of ammonium bicarbonate (Levine & Smith, 2005), fermentation (Baardseth et al., 2006), addition of amino acids like glycine (Bråthen et al., 2005), etc. As Rommens et al. (2008) reported an eventual replacement of existing potatoes by low-asparagine varieties would lower the ingestion of acrylamide by approximately 30% but still some acrylamide can form in the processed products. In the investigations of Pedreschi et al. (2007) potato strip immersion in citric acid solution of 10 gL^{-1} reduced the acrylamide formation during frying more than the strip immersion in sodium pyrophosphate solution of 10 gL^{-1} (53% vs. 17%, respectively – average values for the three temperatures tested). Acrylamide formation decreased dramatically as the frying temperature decreased from 190 to 150 °C for all the pre-treatments tested (Pedreschi et al., 2007).

One of the novel methods for reducing of acrylamide content in final products is application of plant phenolics in technological process. As Yanbing et al. (2015) are summarising, plant polyphenols, one part of phytochemicals, have attracted a great deal of attention for its natural antioxidative feature. After the discovery of acrylamide in food, plant polyphenols were applied to inhibit acrylamide formation. The influence of polyphenols was depended on the structure, concentrations, and antioxidant capacity, as well as reaction conditions, but also some other mechanisms were involved (Yanbing et al., 2015). In the study of Zhang et al. (2007) potato crisps and French fries were immersed into different contents of antioxidant of bamboo leaves (AOB) solution, and the frying processing parameters were optimized. The results of this research showed that nearly 74.1% and 76.1% of acrylamide in potato crisps and French fries was reduced when the AOB addition ratio was 0.1% and 0.01% (w/w), respectively. The maximum inhibitory rate was achieved when the immersion time was designed as 60 s. Zhang & Zhang (2007) investigated the efficiency of antioxidant of bamboo leaves (AOB) and extract of green tea (EGT) on the reduction of acrylamide in fried bread sticks and summarized the optimal levels of two additives. Results showed that nearly 82.9% and 72.5% of acrylamide were reduced when the addition levels of AOB and EGT were 1 and 0.1 g kg^{-1}, respectively. The study indicated that both AOB and EGT could significantly reduce the acrylamide content generated in fried bread sticks and keep original flavour and crispness of fried bread sticks (Zhang & Zhang, 2007). The addition of rosemary extract to the frying oil significantly ($P < 0.05$) reduced the acrylamide content by up to 38%. The significantly smaller change in acrylamide concentration in the potato deep-fried in oil with the addition of rosemary extract compared to potato deep-fried in oil with the addition of butylatedhydroxyanisole (BHA), tertiary butylhydroquinone (TBHQ), and the tocopherols ($P < 0.05$) showed that this rosemary

extract has exceptional carry-over protective effects for deep-fried food, because of its high heat stability (Urbančič et al., 2014).

Many aromatic plants contain compounds that can act as natural antioxidants (Raghavan, 2000). The antioxidant characteristics of plant derived materials can be attributed to their polyphenols. Many plants of *Umbelliferae* family also contain several bioactive phytochemicals such as flavonoid and coumarins, which are reported to have curative, preventive, or nutritive value (Cherng et al., 2008).

Latvian plants lovages are characteristic for our region, but they are rarely used as food ingredient in nowadays. Lovages already from ancient times have been used as herbal plant (Raghavan, 2000). They contain relevant amounts of plant phenolics and other natural antioxidants. Lovage (*Levisticumofficinale* L.) is a perennial herb belonging to the *Umbelliferae* family, with a characteristic earthy, celery-like flavour and smell (Szebeni-Galambosi et al., 1992). All parts of the plant being strongly aromatic with a characteristic earthy, celery-like flavour and smell (Szebeni-Galambosi et al., 1992; Raghavan, 2000). Seeds, leaves and roots of lovage (fresh, powdered and as essential oils), are commonly used in Europe for flavouring foods and beverages and for their medicinal properties (Cu et al., 1990). Lovage root has also been known for centuries as a medicine possessing spasmolytic, diuretic and carminative activities (Raghavan, 2000).

Lovage bioactivity is the basis for the selection of this plant for investigations of possible reduction of acrylamide and other quality changes in fried products. Therefore the aim of the current research was to determine the effect of lovage extracts on the formation of acrylamide in French fries.

MATERIALS AND METHODS

Raw materials

Fresh lovage (*Levisticumofficinale* L.) leaves were collected in Latvia in June 2015 and frozen (-20 ± 2 °C) immediately after collection.

Potatoes 'Lenora' were grown in experimental fields of State Priekuli Plant Breeding institute in 2015. For experiments potatoes were washed, peeled and sliced into strips (0.8 × 0.8 × 6 cm) by longest distance.

Extraction procedure of phenolic compounds from lovage

For extraction of phenolic compounds from lovage as solvents water and ethanol were used. According to the previous investigations (Tomsone, 2015) the lovage leaves were chosen as the plant material for extract using ultrasonic facilitated extraction. Two extracts were used. Both extracts were prepared using ultrasound assisted extraction (UAE) where the output power was 250 W and the frequency was 50 kHz.

The extract with ethanol was made at room temperature +21 ± 2 °C, but the water extracts were prepared at +60 °C temperature for better extraction.

The first extract was water extract of lovage leaves. Frozen lovage leaves (95 g) were homogenized and placed into conical flask in which 500 mL water were added. Then the flask was sonicated one hour in an ultrasonic water bath at 60 °C temperature for better extrction. Extracts were cooled till room temperature and then filtered (cellulose filter paper No.89).

The second extract was 95% ethanol extract of lovage leaves. Frozen lovage leaves (95 g) were homogenization and placed into conical flask in which 1 L ethanol wasadded. Then the flask was sonicated one hour in an ultrasonic water bath at ambient temperature. Extracts were filtered (filter paper No. 89).

The extraction process was performed using single extraction process (without re-extracting) and repeated in triplicate. For extracts total phenol content and radical scavenging activity was determined (in triplicate for each extraction).

French fries preparation technology

Potatoes were divided into 12 batches (four samples in three replications) and each was treated separately. Potato samples were first blanched in hot water (85 °C 8 min) and subjected to analysis. After blanching samples were sprayed or immersed in lovage-water extract or sprayed with ethanol extract (Table 1). After spraying with lovage extracts and immersion in water extract the sample were left for 10 min at room temperature (+20 ± 1 °C) before frying.

Table 1. The abbreviations of the samples used in experiments

Sample codes	Explanation	Extract ratio (g g^{-1}), treatment time (min)
C_B	control, blanched	without additional treatment
SW_B	sprayed with water extract, blanched	ratio extract/potatoes=11/200, 10
IMW_B	immersed in water extract, blanched	ratio extract/potatoes=190/200, 10
SE_B	sprayed with ethanol extract, blanched	ratio extract/potatoes=11/200, 10
C_F	control, fried	
SW_F	sprayed with water extract, fried	
IMW_F	immersed in water extract, fried	
SE_F	sprayed with ethanol extract, fried	

After treatment all samples were fried in oil (180 ± 2 °C) for 7 minutes (200 g potatoes in 1l of oil).Rapeseed oil 'Oleina' produced in Kruszwica, Poland was used for frying. For further chemical analyses average sample combining French fries from three replications were used.

Physical analysis

For lovage leaves and potatoes samples the moisture content was determined according to the standard ISO 6496:1999 and all results were expressed on dry basis. pH was measured by JENWAY 3510 pH-meter, standard method LVS ISO 5542:2010.

Texture analyses

The textural properties of potato straws were measured in terms of the cutting force. A texture Analyzer TA.HDplus (Stable Microsystems, UK) was used for cutting force determination. Potato straws were cut using blade set with knife (HDP/BSK), moving at a pre-test speed 1.00 mm s^{-1}, and test speed of 10 mm s^{-1} over a distance of 15.0 mm. The numerical results were expressed in N.

Chemical analysis

Extraction of phenolic compounds from potatoes

The homogenized samples were extracted with ethanol (80/20 w/w) in a conical flask with a magnetic stirrer (magnet 4.0 × 0.5 cm) at 700 rpm for 1 h at room temperature (20 ± 1 °C). The extracts were then filtered (paper No.89). The extraction process was done in triplicate.

Determination of total phenolic compounds

The total phenolic content (TPC) of the lovage and potato extracts was determined according to the Folin-Ciocalteu spectrophotometric method (Singleton et al., 1999) with some modifications. The absorbance was measured at 765 nm and total phenols were expressed as the gallic acid equivalents (GAE) 100 g^{-1} dry weight (DW) of plant material.

Determination of total flavonoid compounds

The total flavonoid content (TFC) was measured by a spectrophotometric method (Kim et al., 2003). To 0.5 mL of extract 2 mL of double distilled H2O was added, and mixed with 0.15 mL of 5% sodium nitrite (NaNO2) (50 g L^{-1}). After 5 min, 0.15 mL of 10% aluminium chloride (AlCl3*6H2O) solution was added. The mixture was allowed to stand for another 5 min, and then 1 mL of the 1M sodium hydroxide (NaOH) was added. The reaction solution was mixed well. After 15 min of incubation at room temperature, the absorbance was measured at 415 nm.

The absorbance was measured at 415 nm and total flavonoids were expressed as catechin equivalents (CE) 100 g^{-1} DW of the lovage.

Determination of antioxidant activity

Antioxidant activity of the plant extracts was measured on the basis of scavenging activities of the stable 2,2-diphenyl-1-picrylhydraziyl (DPPH$^{\bullet}$) radical as outlined by Yu et al. (2003). The absorbance was measured at 517 nm. The radical scavenging activity (RSA) of extract was also measured by 2,2-azino-bis(3-ethylbenz-thiazoline-6-sulfonic) acid (ABTS$^{\bullet+}$) radical cation assay (Re et al., 1999). For the assessment of extracts, the ABTS$^{\bullet+}$ solution was diluted with a phosphatebuffersolution to obtain the absorbance of 0.800 ± 0.030 at 734 nm. The RSA was expressed as TE 100 g^{-1} DW of plant material. The higher the Trolox equivalent antioxidant capacity (TEAC) of a sample, the stronger the antioxidant activity.

Determination of vitamin C

The content of ascorbic acid was determined by titration with 0.05-M iodine solution (Jansons, 2006; Kampuse et al., 2014). The French fries samples (12.5 g) were poured with 50 mL6% solution of oxalic acid and homogenized. Then the sample was filtered. 2 mL of 1% solution of starch was added to 10 mL of filtrate and the filtrate was titrated until the colour changed which did not disappear during a 30 sec interval. For standard solution of ascorbic acid 20 mg of ascorbic acid were dissolved in 100 mL of the oxalic acid solution. Two mL of the starch solution was added to 25 mL of the standard-solution and the mixture was titrated. The content of vitamin C (ascorbic acid) mg per 100 g of the product dry matter was calculated using the following equation (1):

$$C = 5{,}000 \cdot \frac{V_{sample}}{m \cdot V_{standard}}, \quad (1)$$

where: V_{sample} – volume of the iodine solution titrated in a sample, mL; $V_{standard}$ – volume of the iodine solution titrated in a standard solution, mL; m – the weight of a sample, g.

Determination of acrylamide content

The content of acrylamide in samples was detected in certified laboratory of Food safety, animal health, and environment scientific institute BIOR using High performance liquid chromatography method (HPLC) Acquity UPLC in combination with mass spectrometer QTRAP 5500.

Sample (1 g), the internal standard (500 ng g^{-1}) and 5 mL of hexane were added into a 50 mL centrifuge tube, then the tube was vortexed. Distilled water (10 mL) and acetonitrile (10 mL) were added followed by the the QuEChERS extraction salt mixture (4 g anhydrous MgSO4 and 0.5 g NaCl). The sample tube was shaken for 1 min vigorously and centrifuged at 4,500 g for 5 min. The hexane layer was discarded, and 1mL of the acetonitrile extract was transferred to a tube containing 50 mg of PSA-sorbent and 150 mg of anhydrous MgSO4. The tubes were vortexed for 30 s and then analysed by liquid chromatography tandem mass spectrometry (LC-MS/MS). The quantitative analysis of acrylamide was based on the pre-treatment of selected final products and performed by LC-MS/MS using a Waters Acquity coupled to a 5500 QTrap mass spectrometer (AB Sciex). The separation of acrylamide was achieved with Luna 3 um HILIC column (50 x 2.00 mm i.d., 3 mm; Phenomenex). Methanol (6%) in acidified acetonitrile (0.1% formic acid) was used as a mobile phase (flow rate 0.3 mL min^{-1}, column temperature 40 °C and injection volume 10 mL). The detection by MS/MS was performed using electrospray ionization in the positive mode. The MRM transitions were m/z 72.0 → 54.9 and 72.0 → 44 for acrylamide and 75.0 → 58.0 for acrylamide-d3. The limit of quantification for acrylamide was 50 mkg kg^{-1}.

Statistical analysis

Experimental results aremeans of three replications and were analyzed by Microsoft Excel 2010 and SPSS 17.00. Analysis of variance (ANOVA) and Tukey's test were used to determine differences among samples. Differences were considered as significant at $p < 0.05$.

RESULTS AND DISCUSSION

Total phenol content and radical scavenging activity in lovage extracts

Extraction of phenolic compounds from lovage was performed using two solvents – water and ethanol. The recovery of polyphenols from plant materials is influenced by the plant matrix, method, solubility in the solvent used for the extraction process (Zhou & Yu, 2004; Spigno et al., 2007; Nićiforović et al., 2010; Michiels et al., 2012). Solvent polarity plays a key role in increasing phenolic solubility (Grigonis et al., 2005; Naczk & Shahidi, 2006; Michiels et al., 2012). The properties of extracting solvents significantly affected the measured total phenolics content (± 25% variation) and antioxidant capacity (up to 30% variation) in fruits and vegetables (Michiels et al., 2012). Solvents, such as methanol, ethanol, acetone, propanol and ethyl acetate have been

commonly used for the extraction of phenolics from fresh product (Durling et al., 2007; Alothman et al., 2009). Due to toxicity, from these solvents only ethanol was selected. Several authors reported ethanol as the best solvent for recovery of polythenols (Grigonis et al., 2005; Tomsone et al., 2012; Tomsone & Krūma, 2013). Although efficiency of water as solvent for phenolic compounds recovery lower (Medouni-Adrar et al., 2015), it was selected due to safety, cost reasons and fits with green extraction approach.

The highest total phenol content (TPC), total flavonoid content (TFC), and also free radical scavenging activity (DPPH) was detected in ethanol extract (Table 1). Results of TPC are lower compared with those obtained by Tomsone et al. (2015) reporting up to 2,205 mg GAE 100 g^{-1} TPC in ethanol extract obtained by Soxlet extract and 1,573 mg GAE 100 g^{-1} TPC in ethanol extract obtained by accelerated solvent extraction.

Similar results also were found in experiments about other plants – leaves of *Moringaoleifera* L., where TFC increased by increasing concentration of ethanol in extraction (Vongsak et al., 2013).But the highest cationic binding capacity (ABTS) was obtained in lovage-water extract (Table 2).

Table 2. Total phenol content (TPC), total flavonoid content (TFC) andantiradicalactivity in lovage extracts depending on solvent

Extract	TPC, mg GAE 100 g^{-1}	TFC, mg CE 100 g^{-1}	DPPH, mM TE100 g^{-1}	ABTS, mM TE 100 g^{-1}
2% lovage water extract	819.01 ± 4.92^{b}	1,210.87 ± 13.88^{b}	52.4 ± 0.45^{b}	**55.73** ± 2.32^{a}
1% lovage ethanol extract	**1,034.08** ± 9.55^{a}	**1,619.93** ± 14.58^{a}	**97.44** ± 3.47^{a}	50.29 ± 0.31^{b}

Extraction is strongly influenced by plant matrix because in the study on *Artemisiaargyi* L. leaves TPC in methanolic extract was higher comparing to aqueous extract, although *Pyrrosialingua* L. leaves showed opposite effect (Cai et al., 2004). Literature data showed that ethanol was the best solvent for extraction of bioactive substances from horseradish roots and leaves (Tomsone et al., 2012; Tomsone & Kruma 2013).

Potato moisture content and pH value

During frying the moisture content and also pH value significantly decreased in all evaluated samples. The highest moisture content after frying was in the sample treated with ethanol extract – it was significantly higher than in the samples treated with water (Table 3).

Table 3. The moisture content and pH value in blanched potatoes and French fries treated with different extracts

Sample	Moisture, %	pH
C_B	70.82 ± 0.26^{b*}	6.17 ± 0.09^{a}
SW_B	73.13 ± 0.02^{a}	5.76 ± 0.13^{b}
IMW_B	72.94 ± 0.18^{a}	5.83 ± 0.18^{b}
SE_B	70.68 ± 0.08^{b}	5.86 ± 0.15^{b}
C_F	42.76 ± 0.84^{d}	5.51 ± 0.1^{c}
SW_F	41.58 ± 0.64^{e}	5.64 ± 0.07^{bc}
IMW_F	40.93 ± 0.61^{d}	5.58 ± 0.06^{c}
SE_F	44.43 ± 1.02^{c}	5.69 ± 0.05^{bc}

*Values, marked with the same letter, are not significantly different at $P < 0.05$.

According to Cheng et al. (2013) water content may affect the distribution and the status of the antioxidant applied, as well as its combination and reaction with acrylamide or its intermediates. There were no significant differences in pH value between processed potatoes after blanching, and also in deep-fried potatoes this parameter did not differ significantly. Frying only a slightly decreased pH value (Table 3). According to the data mentioned in literature, the pH values between 7.0 and 8.0 are the most suitable ones for acrylamide formation. Therefore, the pH value can be adjusted to a lower value to reduce the formation of acrylamide in industrial applications (Weisshaar, 2004; Mestdagh et al., 2008; Cheng et al., 2013). Relatively low pH values (5.51–5.69) in fried potatoes of our experiment could result in lower acrylamide content in the end product.

TPC

After treatment with water extracts the total phenol content of the samples did not increase significantly ($P > 0.05$), but after frying with ethanol sprayed fries had significantly ($P < 0.05$) higher phenol content. During frying the highest TPC loss (33.92%) was detected in an aqueous extract soaked fries, but the lowest - with ethanol sprayed fries (24.27%).

DPPH

The highest free radical binding capacity similarly as to TPC was in blanched and in lovage-water extract soaked samples although the differences between treated samples were not significant. But after frying the DPPH activity for all treated samples were even lower than in a control sample, and the lowest it was in a sample soaked in lovage-water extract – the decrease of DPPH was 52.41%.

ABTS

The cationic binding capacity (ABTS) after frying did not significantly change for control sample, but it was decreased in the samples treated with water extract (for 10.74–13.42%).For the samples treated with ethanol extract the ABTS activity even increased by 6.47%. These samples showed the significantly higher ABTS activity both before and after frying. Different ABTS results from the DPPH (Table 4) could be explained with other reaction mechanism.

Table 4. The total phenol content (TPC) and antiradical activity DPPH and ABTS

Sample	TPC, mg 100 g^{-1}DW	DPPH, mg 100 g^{-1}DW	ABTS, mg 100 g^{-1}DW
C_B	147.19 ± 4.13a	10.28 ± 0.34b	6.13 ± 0.17e
SW_B	147.56 ± 1.48a	10.96 ± 0.34a	8.27 ± 0.2c
IMW_B	149.35 ± 4.84a	11.01 ± 0.28a	7.82 ± 0.4c
SE_B	148.24 ± 1.95a	10.88 ± 0.41a	8.97 ± 0.25b
C_F	102.78 ± 1.51c	5.82 ± 0.14c	6.27 ± 0.33e
SW_F	103.7 ± 0.82c	5.59 ± 0.17c	7.16 ± 0.12d
IMW_F	98.69 ± 1.06d	5.24 ± 0.13d	6.98 ± 0.2d
SE_F	112.26 ± 2.48b	5.73 ± 0.15c	9.55 ± 0.17a

*Values, marked with the same letter, are not significantly different at $P < 0.05$.

ABTS + radical is stable and is much more active than DPPH· radical. ABTS radical cation reactions with antioxidant is faster than the millisecond (Naik et al., 2003). ABTS reacts with most of the antioxidants, it does not affected by the ionic strength and is used to determine both hydrophilic and hydrophobic antioxidant activity (Martysiak-Żurowska & Wenta, 2012). Also the results of a variety of foods suggest that ABTS assay better reflects the antioxidant contents than DPPH assay and the correlation between antioxidant capacities detected by ABTS and DPPH assays was strong in fruits and beverages, but lower in vegetables. Most analysed vegetables showed much lower antioxidant capacities as measured by DPPH assay relative to ABTS assay (Floegel et al., 2011). Also experiments about potatoes showed that the ABTS value did not change significantly after frying of crisp (Kita et al., 2013).

Vitamin C content

The vitamin C content in all samples during frying decreased significantly ($P < 0.05$). Comparing the vitamin C content of potato samples after treatment with various lovage extracts the highest ascorbic acid content was found in the sample, which was sprayed with a water extract, while during frying in oil the highest ascorbic acid content remained in the sample, which was sprayed with lovage ethanol extract (Table 4). Regarding correlation between vitamin C content and acrylamide formation the authors Cheng et al. (2013) in their review paper gave the conclusions from the investigations of other researchers that there is a relatively weak reduction of the acrylamide formation by the addition of ascorbic acid to a potato model. Analysing the data of our experiment there can be found a tendency that higher vitamin C content in samples sprayed and immersed in water before frying could influence the formation of lower acrylamide content after frying although some more experiments are necessary to prove such hypothesis.

The hardness of French fries

Comparing the effects of the extract on the French fries straw hardness, it was determined that the least difference in hardness of a straw from a control sample was in the sample that was sprayed with water extract (Table 5). The highest maximal breaking force of fried potatoes was detected for sample IMW, but the lowest for sample SE.

The acrylamide content

The lowest acrylamide content was found in sample, which was sprayed with lovage-water extract. Also to a second sample, which was soaked in water, detected acrylamide content was significantly lower than in the control sample. But in sample sprayed with an alcohol solution acrylamide content after frying was even higher than to the control sample (Table 5).

This phenomenon could be explained with the reactions between ethanol and some chemical components of potatoes and lovage, and formation of chemical components which can join into the reactions of acrylamide formation.

Table 5. The vitamin C content, hardness of straws, and acrylamide content in blanched potatoes and French fries treated with different lovage extracts

Sample	Ascorbic acid, mg 100 g^{-1} DW	Hardness of straws, N	Acrylamide content, μg kg^{-1} dryweight
C_B	39.05 ± 2.63b,c	-	-
SW_B	55.35 ± 1.48e	-	-
IMW_B	50.01 ± 2.83d	-	-
SE_B	46.55 ± 0.00d	-	-
C_F	33.18 ± 1.34a	17.79 ± 4.66a	527.6 ± 12c
SW_F	35.70 ± 0.66a,b,c	18.03 ± 6.25a	349.2 ± 9a
IMW_F	34.93 ± 0.00a,b	19.77 ± 4.29a	380.9 ± 10b
SE_F	40.00 ± 1.38c	15.40 ± 5.26a	584.9 ± 11d

Similarly the authors Cheng et al. (2013) summarized that the preparative procedure, which often includes heat-assisted extraction or concentration steps, may change the composition of the extract, thus making it different from the raw material or the representative component, especially for heat unstable antioxidants. Also, since the extract is relatively complicated compared to pure compounds, the effect of co-extracts and interaction between representative components and the co-extracts should be taken into consideration. Previously, food researchers and technologists applied both antioxidative extracts and pure antioxidants to inhibit acrylamide generation. But both positive and negative results had been obtained (Cheng et al., 2013).

CONCLUSIONS

Summarizing the results, it can be concluded that the best method for potato straw treatment is the spraying with lovage-water extract. Potato straws processed with this method contained by about 32% less acrylamide than the control sample, thus it can be concluded that treatment with lovage-water extract has a positive effect on the acrylamide content reduction in French fries and is a basis for further research on the detection of the optimal lovage-extract concentration.

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