Physical, Chemical and Sensory Characterization of Deep-Fried Fresh-Cut Potatoes Coated with Hydrocolloid/Herbal Extracts

Running head: Fried Coated Potatoes with Herbs

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SUMMARY

Research background. Recently, natural plant extracts have been used to increase the nutritional value of food and to potentially reduce the absorbed fat and formation of the acrylamide in fried foods. Literature data on use of edible polymers with nettle or olive leaf extracts is scarce.

Experimental approach. The effect of novel coatings on colour, fat absorption, phenolic and sugar content, and acrylamide formation in deep fat fried fresh-cut potatoes was evaluated. Extracts of olive and nettle leaves were incorporated in carboxymethyl cellulose (CMC) and gum arabic (GA), used as coatings for potatoes and applied before frying. This aimed to improve the nutritional quality of deep fat fried fresh-cut potatoes.

Results and conclusions. Enrichment of the edible coatings with extracts resulted in a significant change in the visible colour of the potatoes before frying. Significant effect of the extract concentration on the sensory characteristics of potatoes was also observed. Most importantly, the perception of characteristic potato odour and taste was not significantly affected by the simple coating. Although higher concentration of extract resulted with higher phenolics content in fried potatoes, sensory scores decreased at higher extract concentration (1.5 %). After frying, fat content in the

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coated potatoes was reduced by about 15 % when compared to the uncoated samples. The type of extract affected the total sugar content in fried potatoes, such that lower total sugar content was measured in samples coated with coatings enriched with olive leaf compared to those with nettle leaf. Only GA coating showed a reducing effect on acrylamide content by 17 %. Based on all obtained results, as CMC and GA coatings did not influence sensory properties, they can be recommended as carriers of functional compounds or as a frying pre-treatment for potatoes with respect to favourable effect on fat and acrylamide content.

Novelty and scientific contribution. Knowledge obtained in this study can be exploited for preparation of coatings with functional compounds used as a pre-treatment for fried food with respect to favourable effect on fat and acrylamide content.

Keywords: minimally processed potato; edible coatings; nettle leaf extract; olive leaf extract; acrylamide; sensory evaluation

INTRODUCTION

The awareness of healthy diet with less fat and more antioxidants has become a daily routine for customers. Fried potato products are one of the most commonly consumed foods in everyday life because they are tasty, affordable and easily accessible. Deep-fat frying is a widely and frequently used method for food preparation (*1,2*). Deep-fat frying process results in heat and mass transfer mechanisms that lead to surface browning, rapid water evaporation and oil absorption or degradation (*3*). However, due to the high fat content and the formation of potentially carcinogenic substances, such as acrylamide (AA), fried foods are often considered part of an unhealthy diet (*4*). It has even been recommended by the European Commission that the levels of AA should be below 500 mg/kg in potato strips compared to the guideline benchmark value (*5*). Food scientists are making great efforts to find new technologies to reduce the uptake of unhealthy fat and the formation of AA in starchy fried foods. Since fried foods are an issue of great social relevance, several review articles on current strategies to reduce fat content have been published in recent years (*6,7*). Acrylamide is usually formed in carbohydrate-rich foods processed at higher temperatures (above 130 °C) (*8*). Moreover, potatoes are rich in asparagine and reducing sugars, which also affect the formation of AA through Maillard reactions (*9*).

Recent studies on reducing oil and AA content have revealed three main strategies, which can be grouped as follows: 1) changing the frying conditions – *e.g.* lowering the frying temperature (*10*) or increasing the content of antioxidants in the frying oil (*11*), 2) modifying the food surface (*6,12-14*) – *e.g.* edible coatings; and 3) different frying or pre-frying techniques (*15*) - application of non-thermal technologies (*16*), air frying (*17*), microwave assisted frying (*18*) or ultrasound treatment (*19*). Edible

coatings are characterized by the formation of protective layers on the sample surface, since oil absorption occurs mainly in the crust (surface) during the initial stages of frying. For this purpose, different hydrocolloids have been used (*6*), including pectin (*20*), cellulose-based coatings (*21*), gums (*22*), etc. More specifically, edible coatings could serve as carriers for food additives such as antioxidants and antimicrobials on the food surface. To improve the properties of edible coatings synthetic [butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA)] or natural antioxidants can be added. Recently, natural antioxidants have been used to increase the nutritional value, and in some cases, as a tool for reducing AA content in foods (*6*). Natural antioxidants are usually extracted from different plants. Having different polyphenol profiles, the effect on processed foods can be different, such as the formation or inhibition of AA. If AA is eliminated, then the accumulation of carbonyls from the Maillard reaction is reduced (*23*). For example, the combination of gum arabic with turmeric, black pepper, cumin, coriander and red chilli was found to inhibit the formation of AA up to 56 % (*24*). Some authors (*12,25*) also reported that water soluble vitamins play an important role in inhibiting the formation of AA. The extract of *Caralluma fimbriata*, an edible succulent cactus, has been shown to stop lipid oxidation by neutralizing free radicals and quenching singlet and triplet oxygen. Thus, the formation of AA during frying at up to 190 °C was reduced (*8*). However, natural essential oils and plant extracts contain volatile chemical compounds with often intense flavour and remarkable colour. Since odour and taste attributes are important factors that influence consumption and overall acceptance of fried foods, this cannot be neglected in the development of novel products, unless they are used as flavour enhancers.

Recently, olive (*Olea europaea* L.) leaves, have become the focus of scientific interest to produce new health-promoting functional foods or ingredients (*26*). This by-product of the olive oil industry is rich in polyphenols that can be recovered by the extraction. Olive leaves extract is rich in polyphenols are belonging specifically to the secoiridoids family (exclusive to the *Oleaceae* family) (*27*).

Stinging nettle (*Urtica dioica* L.) is a plant rich in antioxidants and is very well known as a home remedy in Mediterranean countries, as anti-cancerogenic treatment (*28*), for food preparations (like bread, pasta, etc.) (*29,30*). Scientific data on its use in edible coatings are very scarce.

The main objective of this study was to examine the efficacy of edible coatings based on two hydrocolloids (carboxymethyl cellulose and gum arabic) and those enriched with nettle and olive leaf extracts on the amount of absorbed fat and formation of AA. Colour, sensory properties and phenolic and sugar profile of fried potatoes were evaluated.

MATERIALS AND METHODS

Materials

Potatoes (*Solanum tuberosum* L. cv. Lady Claire) were supplied by the snack industry (Intersnack Adria Ltd., Hercegovac, Croatia). Cv. Lady Claire is a well-known Dutch industrial potato commonly used in the snack industry. The potatoes were grown and harvested in 2019 in the Slavonia region (Croatia) (45°40'N, 17°1'E). Harvested potatoes were treated with an anti-sprouting agent (Gro Stop Basis and Gro Stop Fog, Certis Europe B.V., Great Abington, UK) and stored in the dark at 8 °C and relative humidity (RH) of about 100 %. Before processing, the potatoes were stored at 16 °C for 3 days. Carboxymethyl cellulose (CMC, V-CMC, Enologica Vason, San Pietro in Cariano, Italy) and gum arabic (GA, Araban, Spray dry, Enologica Vason, San Pietro in Cariano, Italy) were used as polymers for coatings. Olive (*Olea europea* L.) leaves were collected in the southern Croatian region, while stinging nettle (*Urtica dioica* L.) leaves were collected in the western part of Croatia. The leaves of both plants were used for the preparation of the antioxidant extracts. Sunflower oil (Zvijezda Ltd., Zagreb, Croatia) was used for the frying experiments. Petrol ether (Carlo Erba Reagents S.A.S., LeVaudreil, France) was used for the Soxhlet extractions. Water was of Milli-Q quality (Millipore Corp., Bedford, MA, USA). All organic solvents were of analytical HPLC quality and were purchased from Sigma-Aldrich (Steinheim, Germany), as well as chlorogenic acid, catechin, epicatechin, D-(−)-fructose (≥99 % GC), D-(+)-glucose (≥99.5 % GC), D-(+)-sucrose (≥99.5 % GC), AA (>99 %) and d3-AA. No further purification of chemicals was performed and only freshly prepared solutions were used.

Olive and nettle leaves extracts

Olive and nettle leaves were air dried at room temperature and then separately ground using a commercial grinder (GT11, Tefal, Rumilly, France). Extraction was performed using a 14 mm ultrasonic probe (UP200Ht, Hielscher-Ultrasound Technology, Teltow, Germany) for 10 min at 200 W and 100 % amplitude with distilled water as extraction solvent. The mass:volume ratio was 1:10. Freshly prepared extracts of olive (OLE) and stinging nettle (NLE) leaves were frozen and freeze-dried for 72 h (Alpha 1-4 LSCplus, Martin Christ Gefriertrocknungsanlagen GmbH, Osterode am Harz, Germany). The freeze-dried powder was vacuum packed and stored in the dark until use.

Preparation of potato samples and coating solutions

Potatoes were peeled by hand, washed and cut into uniform strips of about 10 mm × 10 mm × 30 mm size using a manual slicer. No chemical washing procedure was applied before and after cutting the potatoes. The strips were then randomly divided into ten groups for coating application.

CMC and GA solutions were prepared by dissolving 1 g of polymer powder in distilled water to obtain 1 % (*m/V*) solutions. The solutions were stirred for 30 min at room temperature (23±2 °C)

until complete dispersion was obtained. For the antioxidant formulations, freeze-dried OLE and NLE powders were added to the coating solutions at two concentrations: 0.75 % or 1.5 % (*m/V)* and stirred for 30 minutes at room temperature to ensure complete solubilisation. Freshly prepared solutions were used for coating.

Application of the coating solutions and frying

Ten different coating formulations were prepared and used to dip the potatoes (CMC, GA and their mixtures with 0.75 or 1.5 % of OLE or NLE). Potatoes dipped only in distilled water were considered as control group. The samples were soaked for 10 min, then dried at room temperature ((23±2 °C), RH 55 %) for 10 min, and finally fried. The whole experiment was done in duplicate.

Coated and uncoated potato strips were deep fried in sunflower oil at (180±2) °C for 10 minutes in an electric deep-fat fryer (F21-RCS1, Tefal, Rumilly, France). In each batch, the samples were individually immersed in the frying oil and the oil was changed for each batch. The oil was drained by shaking the frying basket, the samples were allowed to drain on paper towels at room temperature (23±2 °C) for 2 minutes and collected for further analysis: colour, water content, fat content, sugars, phenolics and AA content. Pictures of the experimental setup are given in Fig. S1.

Colour measurement

Colour was measured with a colorimeter (CHROMA METER CR-5, Konica Minolta, Tokyo, Japan) using the CIE Lab colour scale L^* (lightness), a^* (redness) and b^* (yellowness). Eight measurements were taken at 25 °C at the locations of each fresh and fried potato strip, and the mean value was recorded. The colour of the control strips was used as a reference. The total colour difference (ΔE^*) was calculated as follows:

$$\Delta E^* = ((\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2) \qquad /1/$$

where all parameters (ΔL^{*2}, Δa^{*2}, Δb^{*2}) were calculated with respect to the samples with coating without extract.

Sensory analysis

The sensory profile of the raw and fried potato samples was determined by nine panellists following previously given procedure (*31*). Panellists were permanent staff and PhD students previously internally trained for performing sensory analysis on potatoes. Samples were served on coded plastic plates and scored using Quantitative Descriptive Analysis (QDA) using a discontinuous scale ranging from 0 (no sensation) to 5 (extremely intense). Raw potatoes were scored for colour (browning intensity), odour (odour 1- specific potato odour and odour 2 - the odour not so specific for potato, but attributed to either the plant or the coating polymer), and texture (firmness and stickiness),

while colour (browning intensity), odour (odour 1 and odour 2), texture (oiliness, firmness and crispiness) and taste (taste 1 - specific potato taste, taste 2 - the taste not so specific for potato, but attributed to either the plant or the coating polymer, sweetness, sourness, saltiness and bitterness) were evaluated for the fried samples.

Determination of moisture and fat content

      The fried coated potato strips were ground using a household blender (BKK 2262, Beko, Istanbul, Turkey) and the obtained puree was used to determine the dry matter by drying in an oven at (105±2) °C to constant mass (*32*). Fat content was measured by Soxhlet extraction in petrol ether (*33*)*.* All analyses were performed in a duplicate.

Determination of phenolics

      For the UPLC analyses, the samples were freeze-dried (Alpha 1-4 LSCPlus) for 24 h and ground. The extraction of phenols was carried out (*34*): the freeze-dried sample (0.5 g) was sonicated with 80 % methanol/1 % formic acid (5 mL *V/V*) in an ultrasonic bath (Elmasonic 40H, Elma, Germany) at 50 °C for 30 min. Subsequently, the obtained extract was centrifuged at 1106.82 × g/10 min (Hettich® Rotofix 32a, Tuttlingen, Germany). The residue was extracted one more time with 5 mL of extraction solvent and the resulting supernatants were combined, filtered into a 10 mL flask and made up with the solvent. The obtained extract was filtered using 0.45 µm filter (Macherey-Nagel GmbH & Co. KG, Düren, Germany) before the UPLC MS^2 analysis.

      UPLC analysis was performed using an Agilent 1290 RRLC instrument (Agilent Technologies, Santa Clara, CA, USA) coupled to a binary gradient pump, autosampler and column compartment. The solvent composition and gradient conditions for the determination of phenols were taken from others (*35*). Separation of phenols was performed on a Zorbax Eclipse Plus C18 column (100 × 2.1 mm, 1.8 µm) (Agilent). Ionization was done by electrospray (ESI) in positive and negative mode (*m/z* 100 to 1000) and the mass spectrometer (QQQ 6430, Agilent, Santa Clara, CA, USA) was operated in dynamic multiple reaction monitoring mode (dMRM) operated with the following source parameters: capillary voltage, +4000/-3500 V, nitrogen drying gas temperature at 300 °C with a flow rate of 11 L/h and the nebulizer pressure at 40 psi. Phenols were identified by comparing retention times and mass spectra with those of commercial standards (catechin, epicatechin and chlorogenic acid). External standard calibration was used for quantification. The individual phenols were expressed as mg/100 g of dry mass (DM). Results are given only for catechin, epicatechin and chlorogenic acid, since they were found as the main compounds in previous study (*34*). All analyses were performed in a duplicate.

Determination of sugars

Determination of sugars was done as previously described (*34*). Sugars were extracted by vortexing the freeze-dried sample (0.4 g) (following the same procedure as described in section 2.8.) and 80 % methanol (4 mL). The resulting mixture was then heated in a water bath at 60 °C for 60 min (occasional vortexing) and centrifuged at 4427.28 × g for 15 min. The supernatant was filtered into a 5 mL flask and made up with the solvent.

Sugars were determined by HPLC on an Agilent 1260 Infinity quaternary LC system (Agilent Technologies, Basel, Switzerland) equipped with a refractive index detector, an automatic injector. An isocratic method with a flow rate of 1 mL/min, a column temperature of 45 °C, and 80 % acetonitrile (*V/V*) as the mobile phase was used to separate sugars on Cosmosil Sugar-D 4.6 IDX250 mm column (Nacalai Tesque, INC., Kyoto, Japan). Before injection, the extracts were filtered through 0.45 μm membrane filter (Macherey-Nagel GmbH & Co. KG, Düren, Germany).

The sugars were identified by comparing their retention times with commercial standards (glucose, fructose and sucrose), and quantification was performed by the calibration method with external standards. The results of individual sugars were expressed in g/100 g DM. All analyses were performed in a duplicate.

Determination of AA

For the extraction and chromatographic procedure, method by (*34*) was applied. A mixture of internal d3-AA standard solution (400 μL, 1000 ng/mL), water (40 mL), and freeze-dried sample (2.0 g) (following the same procedure as described in section 2.8.) was manually shaken (15-30 sec), vortexed (15 s) and then stirred for 60 min. The extract was then cooled (+4 °C for 10 min) and centrifuged (1593.82 × g/20 min). The supernatant (10 mL) was purified by solid phase extraction (SPE) clean-up procedures using Isolute Multimode (1 g, 6 mL) and Isolute Env+ (0.5 g, 6 mL) SPE columns (IST, Hengoed, Mid Glamorgan, UK). The obtained extract was then evaporated at 30 °C (Eppendorf Concentrator Plus, Fisher Scientific, Leicestershire, England) to an approximate volume of 500 μL, filtered through 0.45 μm membrane filter and analysed by UPLC MS^2.

The determination of AA was performed using an Agilent UPLC system (Agilent 1290 RRLC, Agilent Technologies, Santa Clara, CA, USA) equipped with an electrospray ion source in positive ion mode as previously described in Section 2.5.3. The column was a Hypercarb TM (5μm, 50 mm × 2.1 mm) with a guard column (5μm, 10 mm × 2 mm) (Thermo Hypersil-Keystone, Bellefonte, PA, USA). Identification was performed by comparing the peak ratios of MRM transitions m/z 54/55 and 44/55 from the sample extracts and standard solutions, and quantification was performed using calibration of the internal d3-AA and AA standards. The results were expressed in μg/kg DM. All analyses were performed in a duplicate.

Statistical analysis

Statistical analysis was performed using Statistica ver. 12.0 software (*36*). Normality of data was tested using Shapiro–Wilk's test and Levene's test was applied for homoscedasticity test. When appropriate, data were analysed using the ANOVA (parametric data) or Kruskal-Wallis test (nonparametric data). Means within groups were compared using Tukey's HSD test or Kruskal-Wallis test. Spearman's rank correlation coefficients were calculated to examine the relationships between dependent variables. The significance level for all tests was $p \leq 0.05$. Results of statistical analysis are presented as least squares means (LS) means±standard errors (SE).

RESULTS AND DISCUSSION

Colour characteristics of potatoes before and after deep-fat frying

The results of colour properties of fresh-cut potatoes before and after deep-fat frying are given in Table 1. The most significant Spearman's correlation data, used for deeper results understanding are not shown in tables.

The uncoated raw fresh-cut sample had all the colour parameters characteristic of raw potatoes (*31,37*). For coated samples before frying, the polymer type had no significant effect on the colour properties (Table 1), while the addition of both extract types resulted in significant differences in L^*, a^* and b^*. Both extracts at both applied concentrations resulted in a significant decrease in brightness. The parameter L^* also showed a very strong correlation with sensory-assessed browning intensity (r_s=-0.80). Thus L^* could be considered as the best indicator of the browning appearance in fresh-cut potato strips. It could be also taken as the most important quality defect that limits the shelf-life and acceptability of fresh-cut potatoes (*38*). When considering a^* and b^* values, the addition of both extracts resulted in an increase in a^* (although negative values were maintained), while b^* *was* slightly decreased. ΔE^* is defined as the overall colour difference with respect to the uncoated sample. Enrichment with both extracts resulted in a significant colour change visible to the human eye (ΔE^*>3). Moreover, the overall colour difference was more visible with increasing concentration of the extracts. Other authors also showed that L^* values were significantly reduced after the treatment of potatoes with rosemary (*39*) or with a green tea essential oil extract (*40)* compared to control samples (soaked in water). The authors also found that increasing the concentration of rosemary essential oil above 4 % (*m/V*) significantly improved the browning of potatoes. In this study, the results of colour parameters obtained by instrumental analysis were in good agreement with those evaluated by sensory panellists (browning intensity).

After frying, the uncoated samples, which served as controls for further comparisons, had a nice goldish colour. Samples with simple coatings and those with both types of extract had lower L^* and higher a^*. There was also very strong correlation between browning intensity and L^* (r_s=-0.66) or

a* (r_s=0.93). Other authors also documented a lower *L** of samples treated with essential oils compared to untreated fried potatoes (*39*). Browning intensity increased noticeably in the coated samples after frying compared to the fried uncoated ones (Table 1). This was especially pronounced in the GA-coated samples; however, it was still perceived as a desirable colour of the deep-fat fried potato according to the panellists. Although there was no statistical difference between extract types, NLE showed a higher influence on browning and the extract concentration showed the most significant ($p<0.001$) influence on all colour attributes.

Sensory characteristics of potatoes before and after deep fat frying

The most important factors for consumer demand of fried products are sensory quality and nutrient contents. According to panellists, the odour and firmness of the raw fresh-cut potato were rated as characteristic for potatoes (Table 2 and Table 3). Some stickiness was also rated. For the coated samples before frying, polymer type and extract type did not have significant effect on firmness and stickiness, while the extract concentration significantly affected stickiness. It was increased with increasing the extract concentration (Table 2). Meanwhile, the firmness was similar for all sample types, regardless of the coating process (both before and after frying).

Although oiliness was less pronounced at lower extract concentrations, crispiness was higher in samples coated with higher extract concentrations. This was considered as a positive effect when compared to control. Accordingly, a very strong positive correlation was found between crispness and oiliness (r_s=0.93) as well as between browning intensity and crispiness (r_s=0.90). Similar to this study, GA was found to increase the crispness of coated potato chips more than CMC (*13*).

As for the firmness and stickiness before frying, polymer type and extract type had no significant effect on odour 1 and 2, while extract concentration significantly decreased odour 1 and increased odour 2 (Table 3). A very strong negative correlation was calculated between browning intensity and potato odour (r_s=-0.92). Edible coatings are aimed at improving the texture of fried food.

After frying, further sensory changes occurred in terms of odour and taste characteristics (Table 3). Samples with extract-enriched coatings had less characteristic potato odour and more intense sourness, especially in NLE samples. This is due to the fact that the extracts used were mainly composed of polyphenols known for their bitter taste. The perception of potato odour (odour 1) and taste (taste 1) was not significantly affected by the polymer type. For the uncoated samples, the odour 1 value was 4.22, then it decreased to 3.94 and 3.84 for CMC and GA, respectively; and to 3.96 and 3.81 for OLE and NLE extract type, respectively. The opposite behaviour was observed for odour 2. Just like for sour taste, taste 2 was more pronounced in the coated samples, with no significant differences between the coating formulations. A strong correlation was observed between odour 2 and odour 1 (r_s=-0.85) and odour 1 and taste 1 (r_s=0.79), indicating that as potato odour decreased,

odour 2 was more pronounced. This was even enhanced at the higher extract (1.5 %) concentration. An effect of rosemary oil concentration on typical potato taste was already shown previously (*39*), but with no consistent trend. Sweetness was higher in the coated samples than in the uncoated samples (with higher values for GA), except for CMC with 1.5 % OLE or NLE. Since sweetness showed a strong positive correlation (r_s=0.74) with taste 1, it can be considered as a favourable characteristic of potato. The coated samples showed a slightly higher saltiness, with no significant differences between the samples. Correlation with sensory properties was observed as follows: odour 1 with browning (r_s=-0.82), odour 2 with browning (r_s=0.74) and sourness with browning (r_s=0.72). Even though perceivable changes of some quality parameters could be scented, the overall organoleptic quality and acceptability of potatoes coated with simple and functionalised (with extract) coatings was good.

Moisture and fat content in fresh-cut deep-fat fried potato

Moisture content in coated fried samples was higher [grand mean value (GM) 55.53 %, Table 2] compared to the uncoated sample (48.49 %), while fat content decreased by 15 %. No significant differences in moisture or fat content were observed between CMC and GA or extract concentration. The results were consistent with those reported previously in the scientific literature (*41*), although they may vary depending on the potato variety, coating type and frying conditions. For example, it was found that guar gum coating reduced fat content in fried potatoes by up to 51.8 % (*41*), while in an another study an increase in fat content was measured in pectin-coated French fries (56.1 %) compared to the control (*42*).

Phenolics in fresh-cut deep-fat fried potato

The predominant phenolic compounds that accounted for 80 % of the total phenolics in raw potatoes were chlorogenic acid (12.1 mg/100 g DM), epicatechin (0.810 mg/100 g DM), and catechin (0.215 mg/100 g DM) (Table 4). The major phenolic compounds identified in the uncoated potato were similar to those identified in previous studies for the cultivar Lady Claire (*34*). During frying of the uncoated samples, the levels of catechin, epicatechin, and chlorogenic acid changed (Table 4). The most remarkable decrease was observed in chlorogenic acid (by about 50 %) and catechin (by about 35 %), while the content of epicatechin was slightly increased. During the exposure to high temperatures, it is possible that phenolics are released from degraded cells (*43*).

In coated samples, the content of total phenolics did not differ significantly considering the polymer or extract type. The only significant difference, more specifically an increase, was observed in the content of chlorogenic acid. This was measured for a higher extract concentration.

After frying, higher content of phenolics was found in the coated potatoes. This was especially evident for contents of catechin and epicatechin. Higher levels of chlorogenic acid were found only in the coated potatoes compared to the uncoated ones after frying. These results could be due to the phenolic content of the extracts or protective role of the coatings. The mechanism of activity of phenolic compounds was previously given in scientific literature, but the specific syntheses and performance of their antioxidant mechanism during frying still remains unclear (*44*). In olive leaves, oleuropein was a predominant compound, followed by rutin, verbascoside, hydroxytyrosol, caffeic acid and chlorogenic acid (*45*). In nettle leaves, cinnamic acids were the most abundant group, followed by flavonols (mainly derivatives of kaempferol and quercetin), flavones, flavan-3-ols (catechin and epicatechin), benzoic acids, coumarins, isoflavones and other acids (*46*). However, chlorogenic acid, catechin and epicatechin were present in olive leaves and nettle, respectively, at levels too low to affect their concentration in potato samples. In contrast, extract concentration affected colour parameters and browning. As phenolics are known to be a substrate for browning processes, further studies are needed in order to better understand the mechanism of all these changes.

Sugars and AA in deep fat fried potato

Main sugars found in potato samples were monosaccharides (glucose and fructose) and disaccharides (sucrose) (Table 4). Their amounts were in the following order: sucrose>glucose>fructose. The content of sucrose and glucose was lower in fried uncoated potatoes when compared to raw potatoes, while the content of fructose remained the same. The decrease in sugar content during frying was probably due to the involvement of these sugars in Maillard reactions. Here, interactions of sugars with amino acids leads to the formation of brownish compounds and to the characteristic odour and taste of the fried potato (*34*). A significant difference between polymer types was only found for fructose content, which was higher in CMC-coated samples. The extract type seemed to have an influence on glucose and sucrose. The amount of extract significantly affected only the glucose content, which is an important precursor in the synthesis of AA. In addition, all sugars were present in all coated samples in the same amount as in the uncoated samples before frying. The same question arises as with phenolics: did the coatings and extracts had any protective role for the sugars or whether this was a consequence of their composition? It is possible that extracts used contained some minor components that remained during the extraction process and were retained in the lyophilised powder, apart from the polyphenols, which could affect the amount of sugar (*26*) and thus the AA content.

AA is considered as a potentially carcinogenic compound (*28*). According to the European Commission Regulation 2017/2158, the upper limit for AA in potato products in relation to the

guideline benchmark value is 500 µg/kg fresh weight (FW) (*5)*. With regards to this, it should be noted that the AA content did not exceed the permitted value in all samples. According to the literature, reducing sugars play a crucial role in AA synthesis (*47*). With increasing content of sugars in potato, aside changes in colour and bitterness, this also leads to the formation of AA in fried potato. For temperatures above 120 °C and with decreasing the water content, AA can be formed as a result of interactions between glucose and fructose with asparagine (48).

In this study, the content of reducing sugars was higher in CMC than in GA and lower AA values were found for GA coated samples (95 µg/kg DM) as compared to the uncoated (115.89 µg/kg DM) while CMC was not as effective as GA. It is possible that GA formed more uniform coating on potato surface than CMC that might have modulated heat transfer from the frying oil to potatoes surface and then the rate of AA formed was reduced. The relation could be also made to the sugar content that was found to be higher in CMC than in GA samples. Since content of sugars play important role in the formation of AA, then in CMC coatings the inhibition effect was less pronounced than in GA. According to literature, GA [1% (*m/V*), soaking for 60 min] reduced the content of AA in fried potatoes by 20 % (*49*), alginic acid solution at 1 % (*m/V*) for 5 h soaking was twice as effective (30 %) as a 5 % (*m/V*) solution for 1 h soaking (60 %) (*20*), while the use of other biopolymer concentrations*, i.e.* alginate (0.3 %), pectin (0.2 %) and chitosan (1 %) reduced AA by 54, 51 and 41 %, respectively (*14*). The most likely explanation is that coatings with hydrocolloids as the main component, alter the texture of foods due to their gelling or thickening properties. Then, they disrupt the molecular interactions between the precursors of AA (*e.g.* glucose and asparagine) with different efficacy (*20,49*).

Treatment with coatings with extracts significantly increased the AA content. Although there are examples in the literature of positive effect of different plant extracts on the reduction of AA, the present study could not confirm these results. Probably, the discrepancy of results could be due to the different chemical composition of used plants and thus produced extracts (*8,50*). Literature data also suggest that the patterns of relative inhibitory activities depend on the type of coating, concentration and soaking time (*14,51*). Even though some ohers (*8*) showed that *C. fimbriata* was effective in decreasing AA content (42.5 µg/kg) in immersed samples, and thus improved nutritional quality, this was not the case in the present study where no positive effect on the nutritional value of fried samples was observed. Literature data (*52*) showed that ginger, borage and fennel reduced AA by 21.91, 66.29 and 29.15 %, respectively, while in other studies (*53*) it was found that the *Allium hertifolium* extract was more effective than that of *Zataria multiflora* in fried potato crisps. Knowledge on the mechanism of action of OLE and NLE remains preliminary for further studies, highlighting the importance of testing novel coating formulations and the variability of results in the scientific literature.

CONCLUSIONS

From the all tested parameters, it appears that the application of simple coatings did not significantly affect potato colour (instrumentally measured or sensory evaluated), odour and taste. On the contrary, by increasing olive and nettle leaves extract concentration led to perceivable changes in organoleptic quality, but it was not so important to affect overall acceptability. It appears that the application of simple coatings can effectively reduce fat absorption in fried fresh-cut potatoes, but most of them did not minimise the formation of AA. Fat content in coated potatoes without extracts was reduced by about 15 % after frying, while extracts of olive and nettle leaves incorporated into edible coatings showed no effect on fat content. The type of coating and extract did not significantly affect phenolics, but in general did affect the increase in sugar in the fried potatoes. Thus, samples with GA coatings were described as having lower sugar content compared to CMC coated samples. Samples enriched with OLE also had lower sugar content than those enriched with NLE. Using olive or nettle extract has the potential to improve the biological quality of deep-fat fried fresh-cut potatoes because higher concentration of extract results with higher phenolic content in fried potatoes, while further investigation is needed to create a formulation with a generally beneficial effect. Only the simple GA coating showed a reducing effect on AA content by 17 %, showing also the lower sugars content. Although it was expected that the effect on fat reduction would be higher, the results obtained can serve as a good indication for further research. Based on all obtained results, CMC but even more simple GA coating can be recommended as carriers of functional compounds or as a pre-treatment for fried potatoes with respect to favourable effect on fat and AA content and not affecting sensorial properties.

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CONFLICT OF INTEREST

Declarations of interest: none.

AUTHORS' CONTRIBUTION

Mia Kurek contributed to the conception, acquisition, analysis, interpretation, draft writing and editing of the paper. Maja Repajić contributed to the conception, acquisition, interpretation and drafting. Mario Ščetar contributed to manuscript drafting. Lea Radošević contributed to acquisition and anaylsis. Sandra Pedišić and Zdenka Pelajić contributed to the sample analysis, and Kata Galić and Branka Levaj contributed to the conception, interpretation and drafting.

SUPPLEMENTARY MATERIAL

Supplementary material is available at: www.ftb.com.hr.

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Table 1. Colour parameters of fresh-cut potato before and after frying

	L^*	a^*	b^*	ΔE^*	Browning intensity	L^*	a^*	b^*	ΔE^*	Browning intensity
			before					after		
Uncoated	68.2±1.5	-2.06±0.25	18.9±1.2	nd	0.28±0.57	74.7±1.4	-3.59±0.31	20.8±1.6	nd	0.94±0.95
Coated/Source of variation										
PT	p=0.208	p=0.177	p=0.505	p=0.06	p=0.666	p=0.241	p=0.247	p=0.038*	p=0.019*	p=0.547
CMC	(62.2±0.6)[a]	(-1.05±0.07)[a]	(16.4±0.4)[a]	(5.32±0.45)[a]	(2.32±0.23)[a]	(68.9±0.6)[a]	(-1.89±0.18)[a]	(23.4±0.4)[b]	(7.59±0.45)[b]	(2.34±0.19)[a]
GA	(63.2±0.4)[a]	(-1.15±0.07)[a]	(17.1±0.4)[a]	(4.45±0.29)[a]	(2.16±0.22)[a]	(69.8±0.6)[a]	(-2.18±0.16)[a]	(22.5±0.3)[a]	(6.29±0.51)[a]	(2.50±0.18)[a]
ET	p<0.001*	p<0.001*	p=0.002*	p=0.375	p=0.043*	p=0.022*	p=0.048*	p=0.683	p=0.024*	p=0.059
OLE	(63.6±0.4)[b]	(-0.85±0.07)[b]	(17.6±0.4)[b]	(4.57±0.33)[a]	(1.91±0.17)[a]	(70.3±0.5)[b]	(-2.29±0.14)[a]	(23.0±0.4)[a]	(6.22±0.42)[a]	(2.20±0.17)[a]
NLE	(61.7±0.5)[a]	(-1.35±0.05)[a]	(15.9±0.3)[a]	(5.20±0.42)[a]	(2.57±0.26)[b]	(68.4±0.6)[a]	(-1.78±0.20)[b]	(22.9±0.4)[a]	(7.66±0.53)[b]	(2.64±0.20)[a]
EC (%)	p<0.001*	p<0.001*	p=0.023*	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p<0.001*
0	(64.7±0.6)[c]	(-1.44±0.05)[a]	(16.1±0.5)[a]	(3.31±0.51)[a]	(0.39±0.11)[a]	(73.7±0.3)[b]	(-3.39±0.06)[a]	(24.0±0.5)[b]	(3.84±0.46)[a]	(1.39±0.20)[a]
0.75	(62.9±0.4)[b]	(-0.80±0.07)[b]	(18.1±0.5)[b]	(5.21±0.30)[b]	(2.76±0.15)[b]	(66.9±0.6)[a]	(-1.95±0.10)[b]	(21.1±0.4)[a]	(8.46±0.52)[b]	(2.58±0.17)[b]
1.5	(60.4±0.5)[a]	(-1.07±0.10)[b]	(16.1±0.4)[a]	(6.14±0.43)[b]	(3.57±0.21)[b]	(67.5±0.4)[a]	(-0.77±0.12)[c]	(23.6±0.3)[b]	(8.51±0.36)[b]	(3.29±0.18)[b]
PT × ET										
	p=0.062	p=0.003*	p=0.110	p=0.364	p=0.069	p=0.496	p<0.001*	p=0.169	p=0.240	p=0.221
CMC × OLE	(63.1±0.7)[a]	(-0.83±0.11)[b]	(16.9±0.6)[a]	(4.78±0.54)[a]	(1.87±0.23)[a]	(69.4±0.8)[a]	(-2.16±0.20)[a]	(22.9±0.7)[a]	(7.13±0.58)[a]	(2.13±0.24)[a]
CMC × NLE	(61.4±0.9)[a]	(-1.28±0.06)[a]	(15.8±0.5)[a]	(5.87±0.71)[a]	(2.78±0.39)[a]	(68.5±0.8)[a]	(-1.63±0.30)[b]	(23.8±0.5)[a]	(8.04±0.68)[a]	(2.56±0.29)[a]
	p=0.002*	p<0.001*	p=0.007*	p=0.688	p=0.314	p=0.020*	p=0.201	p=0.030*	p=0.006*	p=0.144
GA × OLE	(64.2±0.4)[b]	(-0.87±0.10)[b]	(18.2±0.6)[b]	(4.37±0.40)[a]	(1.94±0.27)[a]	(71.3±0.6)[b]	(-2.43±0.18)[a]	(23.1±0.4)[a b]	(5.30±0.56)[a]	(2.28±0.23)[a]
GA × NLE	(62.1±0.5)[a]	(-1.43±0.07)[a]	(16.1±0.4)[a]	(4.53±0.42)[a]	(2.37±0.35)[a]	(68.3±0.9)[a]	(-1.94±0.27)[a]	(21.9±0.5)[a]	(7.27±0.81)[b]	(2.72±0.29)[a]
PT × EC (%)										
	p<0.001*	p<0.001*	p=0.139	p=0.003*	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p<0.001*
CMC × 0	(65.0±1.1)[b]	(-1.45±0.09)[a]	(16.7±0.8)[a]	(4.10±0.92)[a]	(0.44±0.16)[a]	(73.6±0.3)[b]	(-3.35±0.11)[a]	(25.1±0.8)[b]	(4.65±0.74)[a]	(1.11±0.24)[a]
CMC × 0.75	(62.4±0.5)[b]	(-0.81±0.10)[b]	(17.3±0.6)[a]	(4.80±0.47)[a b]	(2.94±0.25)[b]	(65.9±0.5)[a]	(-1.78±0.13)[b]	(20.8±0.5)[a]	(9.28±0.44)[b]	(2.64±0.24)[b]
CMC × 1.5	(59.3±0.7)[a]	(-0.90±0.12)[b]	(15.1±0.6)[a]	(7.07±0.70)[b]	(3.58±0.31)[b]	(67.3±0.6)[a]	(-0.55±0.16)[c]	(24.2±0.3)[b]	(8.83±0.51)[b]	(3.28±0.26)[b]
	p=0.005*	p=0.002*	p=0.003*	p<0.001*	p<0.001*	p<0.001*	p<0.001*	p=0.025*	p<0.001*	p=0.001*
GA × 0	(64.4±0.5)[b]	(-1.42±0.06)[a]	(15.5±0.4)[a]	(2.52±0.56)[a]	(0.33±0.16)[a]	(73.9±0.5)[b]	(-3.43±0.07)[a]	(23.1±0.5)[b]	(3.03±0.50)[a]	(1.67±0.32)[a]
GA × 0.75	(63.5±0.6)[a b]	(-0.79±0.10)[b]	(18.9±0.8)[b]	(5.62±0.56)[b]	(2.58±0.16)[b]	(67.9±1.1)[a]	(-2.13±0.13)[b]	(21.4±0.6)[a]	(7.64±0.91)[b]	(2.53±0.26)[a b]
GA × 1.5	(61.6±0.5)[a]	(-1.24±0.14)[a]	(17.1±0.4)[a b]	(5.22±0.56)[b]	(3.56±0.29)[b]	(67.6±0.6)[a]	(-0.99±0.18)[c]	(23.0±0.5)[a b]	(8.19±0.52)[b]	(3.31±0.26)[b]

CMC=carboxymethyl cellulose, GA=gum arabic, OLE=olive leaves extract, NLE=nettle leaves extract, nd=not determined, PT=polymer type, ET=extract type, EC=extract concentration (%). Browning intensity was evaluated by sensory panel. Results for the uncoated sample are expressed as mean±SD and results for coated samples are expressed as mean±SE. Values with different letters within column are statistically different at p≤0.05

Table 2. Texture, sensory properties, moisture and fat content of fresh-cut potato before and after frying

	Stickiness	Firmness		Oiliness	Crispiness	w(moisture)/%	w(fat)/%
Frying	before	before	after	after	after	after	after
Uncoated	0.56±1.33	4.89±0.33	1.67±1.12	1.44±1.13	1.00±0.87	48.5±1.6	10.31±0.08
Coated/Source of variation							
PT	p=0.215	p=0.786	p=0.760	p=0.510	p=0.867	p=0.908	p=0.690
CMC	(2.17±0.22)[a]	(4.76±0.07)[a]	(1.97±0.12)[a]	(1.61±0.16)[a]	(1.79±0.15)[a]	(54.8±1.1)[a]	(8.71±0.12)[a]
GA	(1.81±0.18)[a]	(4.72±0.08)[a]	(1.98±0.15)[a]	(1.74±0.16)[a]	(1.78±0.16)[a]	(56.3±2.1)[a]	(8.78±0.20)[a]
ET	p=0.942	p=0.659	p=0.959	p=0.103	p=0.011*	p=0.166	p=0.127
OLE	(1.94±0.19)[a]	(4.76±0.06)[a]	(1.96±0.13)[a]	(1.48±0.16)[a]	(1.49±0.13)[a]	(55.2±2.1)[a]	(8.89±0.16)[a]
NLE	(2.04±0.21)[a]	(4.72±0.09)[a]	(1.99±0.14)[a]	(1.87±0.16)[a]	(2.07±0.17)[b]	(55.9±1.1)[a]	(8.60±0.16)[a]
EC	p=0.004*	p=0.703	p=0.258	p=0.009*	p=0.002*	p=0.867	p=0.142
0	(1.33±0.26)[a]	(4.83±0.06)[a]	(2.06±0.13)[a]	(1.17±0.19)[a]	(1.22±0.16)[a]	(56.4±3.2)[a]	(8.51±0.17)[a]
0.75	(2.25±0.21)[b]	(4.64±0.12)[a]	(2.11±0.19)[a]	(1.83±0.19)[ab]	(2.04±0.21)[b]	(55.3±1.4)[a]	(8.99±0.16)[a]
1.5	(2.39±0.23)[b]	(4.75±0.09)[a]	(1.76±0.16)[a]	(2.03±0.18)[b]	(2.08±0.17)[b]	(54.9±1.3)[a]	(8.74±0.25)[a]
PT × ET	p=0.625	p=0.848	p=0.745	p=0.535	p=0.016*	p=0.172	p=0.603
CMC × OLE	(2.04±0.30)[a]	(4.81±0.08)[a]	(1.93±0.17)[a]	(1.48±0.21)[a]	(1.43±0.17)[a]	(52.9±1.4)[a]	(8.63±0.17)[a]
CMC × NLE	(2.30±0.31)[a]	(4.70±0.13)[a]	(2.02±0.17)[a]	(1.74±0.24)[a]	(2.15±0.23)[b]	(56.6±1.5)[a]	(8.79±0.18)[a]
	p=0.616	p=0.430	p=0.835	p=0.112	p=0.224	p=1.000	p=0.009*
GA × OLE	(1.85±0.24)[a]	(4.70±0.10)[a]	(2.00±0.20)[a]	(1.48±0.24)[a]	(1.56±0.19)[a]	(57.4±3.9)[a]	(9.16±0.25)[b]
GA × NLE	(1.78±0.28)[a]	(4.74±0.13)[a]	(1.96±0.22)[a]	(2.00±0.21)[a]	(2.00±0.26)[a]	(55.2±1.7)[a]	(8.41±0.24)[a]
PT × EC	p=0.072	p=0.945	p=0.581	p=0.006*	p=0.005*	p=0.513	p=0.734
CMC × 0	(1.44±0.43)[a]	(4.78±0.10)[a]	(2.11±0.14)[a]	(0.89±0.24)[a]	(1.11±0.21)[a]	(52.9±2.0)[a]	(8.64±0.34)[a]
CMC × 0.75	(2.39±0.31)[a]	(4.72±0.16)[a]	(2.03±0.27)[a]	(1.78±0.24)[ab]	(2.08±0.27)[b]	(55.1±2.2)[a]	(8.67±0.07)[a]
CMC × 1.5	(2.67±0.33)[a]	(4.78±0.13)[a]	(1.78±0.21)[a]	(2.17±0.26)[b]	(2.17±0.23)[b]	(56.4±1.7)[a]	(8.82±0.17)[a]
	p=0.059	p=0.380	p=0.395	p=0.458	p=0.216	p=1.000	p=0.056
GA × 0	(1.22±0.32)[a]	(4.89±0.08)[a]	(2.00±0.23)[a]	(1.44±0.28)[a]	(1.33±0.26)[a]	(59.8±5.8)[a]	(8.39±0.28)[a]
GA × 0.75	(2.11±0.29)[a]	(4.56±0.18)[a]	(2.19±0.27)[a]	(1.89±0.30)[a]	(2.00±0.32)[a]	(55.5±2.1)[a]	(9.31±0.22)[a]
GA × 1.5	(2.11±0.31)[a]	(4.72±0.14)[a]	(1.75±0.26)[a]	(1.89±0.27)[a]	(2.00±0.24)[a]	(53.5±1.8)[a]	(8.65±0.50)[a]

CMC=carboxymethyl cellulose, GA=gum arabic, OLE=olive leaves extract, NLE=nettle leaves extract, PT=polymer type, ET=extract type, EC=extract concentration (%) Results for the uncoated sample are expressed as mean±SD and results for coated samples are expressed as mean±SE. Values with different letters within column are statistically different at p≤0.05

Table 3. Odour and taste sensory properties of fresh-cut potato before and after frying

	Odour 1	Odour 2	Odour 1	Odour 2	Taste 1	Taste 2	Sweetness	Sourness	Saltiness	Bitterness
Frying	before		after		after		after		after	
Uncoated	4.56±0.73	0.00±0.00	4.22±0.97	0.22±0.67	4.11±1.27	0.56±1.13	0.78±1.56	0.11±0.33	0.89±1.17	0.67±1.00
Coated/Source of variation										
PT	p=0.453	p=0.906	p=0.597	p=0.931	p=0.694	p=0.387	p=0.322	p=0.757	p=0.657	p=0.492
CMC	(3.76±0.17)^a	(0.84±0.15)^a	(3.94±0.12)^a	(0.50±0.11)^a	(3.73±0.17)^a	(0.78±0.16)^a	(0.93±0.17)^a	(0.35±0.08)^a	(0.70±0.14)^a	(0.77±0.14)^a
GA	(3.54±0.19)^a	(0.85±0.15)^a	(3.84±0.12)^a	(0.52±0.11)^a	(3.70±0.15)^a	(0.54±0.12)^a	(1.13±0.17)^a	(0.41±0.09)^a	(0.76±0.13)^a	(0.97±0.16)^a
ET	p=0.082	p=0.545	p=0.394	p=0.899	p=0.718	p=0.306	p=0.461	p=0.037*	p=0.326	p=0.906
OLE	(3.80±0.20)^a	(0.82±0.16)^a	(3.96±0.12)^a	(0.56±0.12)^a	(3.74±0.16)^a	(0.80±0.16)^a	(1.00±0.18)^a	(0.28±0.09)^a	(0.69±0.14)^a	(0.93±0.16)^a
NLE	(3.50±0.16)^a	(0.87±0.14)^a	(3.81±0.12)^a	(0.46±0.10)^a	(3.69±0.16)^a	(0.52±0.12)^a	(1.06±0.16)^a	(0.48±0.09)^b	(0.78±0.13)^a	(0.81±0.14)^a
EC	p<0.001*	p<0.001*	p<0.001*	p=0.002*	p=0.095	p=0.224	p=0.147	p=0.020*	p=0.648	p=0.199
0	(4.50±0.17)^b	(0.33±0.17)^a	(4.28±0.14)^b	(0.22±0.11)^a	(3.89±0.22)^a	(0.78±0.20)^a	(1.39±0.25)^a	(0.22±0.11)^a	(0.89±0.19)^a	(0.83±0.18)^a
0.75	(3.39±0.18)^a	(0.90±0.14)^b	(3.92±0.12)^{ab}	(0.44±0.12)^{ab}	(3.82±0.18)^a	(0.42±0.15)^a	(1.03±0.18)^a	(0.36±0.10)^{ab}	(0.75±0.18)^a	(0.72±0.20)^a
1.5	(3.06±0.24)^a	(1.31±0.20)^b	(3.47±0.15)^a	(0.86±0.16)^b	(3.44±0.19)^a	(0.78±0.17)^a	(0.67±0.15)^a	(0.56±0.12)^b	0.56±0.13)^a	(1.06±0.18)^a
PT × ET	p=0.157	p=0.559	p=0.193	p=0.736	p=0.465	p=0.508	p=0.862	p=0.008*	p=0.227	p=0.977
CMC × OLE	(3.96±0.26)^a	(0.80±0.22)^a	(4.09±0.16)^a	(0.52±0.17)^a	(3.85±0.23)^a	(0.93±0.26)^a	(0.96±0.26)^a	(0.15±0.09)^a	(0.63±0.21)^a	(0.81±0.21)^a
CMC × NLE	(3.56±0.23)^a	(0.89±0.21)^a	(3.78±0.17)^a	(0.48±0.14)^a	(3.61±0.26)^a	(0.63±0.20)^a	(0.89±0.22)^a	(0.56±0.13)^b	(0.78±0.19)^a	(0.72±0.17)^a
	p=0.298	p=0.791	p=0.891	p=0.619	p=0.822	p=0.420	p=0.396	p=0.730	p=0.803	p=0.842
GA × OLE	(3.63±0.31)^a	(0.85±0.23)^a	(3.83±0.18)^a	(0.59±0.17)^a	(3.63±0.23)^a	(0.67±0.20)^a	(1.04±0.26)^a	(0.41±0.14)^a	(0.74±0.19)^a	(1.04±0.25)^a
GA × NLE	(3.44±0.23)^a	(0.85±0.20)^a	(3.85±0.16)^a	(0.44±0.14)^a	(3.78±0.20)^a	(0.41±0.14)^a	(1.22±0.22)^a	(0.41±0.12)^a	(0.78±0.19)^a	(0.91±0.22)^a
PT × EC	p<0.001*	p=0.009*	p=0.002*	p<0.001*	p=0.239	p=0.718	p=0.322	p=0.156	p=0.638	p=0.357
CMC × 0	(4.67±0.23)^b	(0.44±0.30)^a	(4.33±0.23)^b	(0.00±0.00)^a	(3.89±0.37)^a	(0.89±0.33)^a	(1.22±0.36)^a	(0.22±0.15)^a	(1.00±0.30)^a	(0.67±0.23)^a
CMC × 0.75	(3.47±0.22)^a	(0.81±0.19)^{ab}	(4.06±0.15)^{ab}	(0.44±0.17)^{ab}	(3.83±0.23)^a	(0.61±0.27)^a	(1.06±0.29)^a	(0.33±0.14)^a	(0.61±0.23)^a	(0.61±0.22)^a
CMC × 1.5	(3.14±0.32)^a	(1.28±0.25)^b	(3.42±0.18)^a	(1.06±0.24^b	(3.47±0.28)^a	(0.83±0.25)^a	(0.50±0.20)^a	(0.50±0.15)^a	(0.50±0.19)^a	(1.03±0.26)^a
	p=0.004*	p=0.004*	p=0.062	p=0.632	p=0.307	p=0.247	p=0.340	p=0.131	p=0.877	p=0.528
GA × 0	(4.33±0.26)^b	(0.22±0.15)^a	(4.22±0.15)^a	(0.44±0.20)^a	(3.89±0.24)^a	(0.67±0.23)^a	(1.56±0.36)^a	(0.22±0.15)^a	(0.78±0.22)^a	(1.00±0.28)^a
GA × 0.75	(3.31±0.28)^a	(1.00±0.22)^b	(3.78±0.19)^a	(0.44±0.17)^a	(3.81±0.29)^a	(0.22±0.13)^a	(1.00±0.24)^a	(0.39±0.14)^a	(0.89±0.28)^a	(0.83±0.34)^a
GA × 1.5	(2.97±0.37)^a	(1.33±0.32)^b	(3.53±0.24)^a	(0.67±0.21)^a	(3.42±0.26)^a	(0.72±0.25)^a	(0.83±0.23)^a	(0.61±0.18)^a	(0.61±0.18)^a	(1.08±0.24)^a

CMC=carboxymethyl cellulose, GA=gum arabic, OLE=olive leaves extract, NLE=nettle leaves extract, nd=not determined, PT=polymer type, ET=extract type, EC=extract concentration (%). Results for the uncoated sample are expressed as mean±SD and results for coated samples are expressed as mean±SE. Values with different letters within column are statistically different at p≤0.05

Table 4. Phenolics, sugars and acrylamide of fresh-cut potato before (for uncoated samples) and after frying

		w(Catechin)/ (mg/100 g DM)	w(Epicatechin)/ (mg/100 g DM)	w(Chlorogenic acid)/(mg/100 g DM)	w(Fructose)/ (g/100 g DM)	w(Glucose)/ (g/100 g DM)	w(Sucrose)/ (g/100 g DM)	w(Acrylamide) /(µg/kg DM)
Uncoated	BF	0.215±0.007	0.810±0.008	12.1±0.0	0.069±0.002	0.167±0.025	0.209±0.015	nd
	AF	0.140±0.006	0.877±0.004	6.6±0.0	0.072±0.003	0.077±0.004	0.155±0.005	116±16
Coated AF/Source of variation								
PT		p=0.662	p=0.298	p=0.127	p<0.001*	p=0.298	p=0.488	p=0.419
CMC		(0.220±0.003)[a]	(1.05±0.04)[a]	(7.3±0.6)[a]	(0.161±0.024)[b]	(0.190±0.017)[a]	(0.182±0.008)[a]	(254±25)[a]
GA		(0.217±0.002)[a]	(1.01±0.06)[a]	(8.3±0.4)[a]	(0.080±0.005)[a]	(0.154±0.005)[a]	(0.186±0.010)[a]	(299±50)[a]
ET		p=0.726	p=0.166	p=0.860	p=0.326	p=0.011*	p<0.001*	p=0.206
OLE		(0.219±0.002)[a]	(1.09±0.06)[a]	(7.8±0.4)[a]	(0.115±0.022)[a]	(0.159±0.015)[a]	(0.164±0.009)[a]	(300±42)[a]
NLE		(0.218±0.002)[a]	(0.97±0.03)[a]	(7.9±0.6)[a]	(0.126±0.020)[a]	(0.185±0.012)[b]	(0.205±0.004)[b]	(253±37)[a]
EC		p=0.076	p=0.523	p=0.043*	p=0.914	p=0.047*	p=0.833	p=0.001*
0		(0.215±0.002)[a]	(1.05±0.04)[a]	(7.0±0.1)[a]	(0.168±0.039)[b]	(0.211±0.021)[b]	(0.198±0.001)[a]	(147±20)[a]
0.75		(0.217±0.002)[a]	(1.05±0.09)[a]	(7.4±0.9)[ab]	(0.099±0.006)[a]	(0.155±0.010)[a]	(0.174±0.015)[a]	(283±49)[ab]
1.5		(0.224±0.004)[a]	(1.00±0.05)[a]	(9.0±0.4)[b]	(0.096±0.006)[a]	(0.150±0.008)[a]	(0.180±0.011)[a]	(399±15)[b]
PT × ET		p=0.859	p=0.077	p=0.255	p=0.748	p=0.018*	p=0.025*	p=0.183
CMC × OLE		(0.221±0.004)[a]	(1.10±0.05)[a]	(7.1±0.6)[a]	(0.160±0.036)[a]	(0.174±0.029)[a]	(0.165±0.011)[a]	(259±28)[a]
CMC × NLE		(0.220±0.004)[a]	(1.00±0.05)[a]	(7.5±1.0)[a]	(0.163±0.035)[a]	(0.205±0.019)[b]	(0.199±0.004)[b]	(248±43)[a]
		p=0.936	p=1.000	p=1.000	p=0.199	p=0.054	p=0.010*	p=0.520
GA × OLE		(0.217±0.002)[a]	(1.08±0.12)[a]	(8.4±0.5)[a]	(0.071±0.002)[a]	(0.144±0.004)[a]	(0.162±0.015)[a]	(340±79)[a]
GA × NLE		(0.217±0.002)[a]	(0.94±0.02)[a]	(8.3±0.7)[a]	(0.090±0.009)[a]	(0.165±0.008)[a]	(0.211±0.005)[b]	(259±65)[a]
PT × EC		p=0.062	p=0.082	p=0.007*	p=0.023*	p=0.018*	p=0.777	p=0.024*
CMC × 0		(0.214±0.003)[a]	(1.15±0.00)[a]	(7.2±0.0)[ab]	(0.272±0.005)[b]	(0.265±0.010)[b]	(0.198±0.001)[a]	(199±5)[a]
CMC × 0.75		(0.217±0.002)[a]	(0.93±0.01)[a]	(5.2±0.1)[a]	(0.104±0.006)[a]	(0.146±0.013)[a]	(0.176±0.012)[a]	(199±22)[a]
CMC × 1.5		(0.230±0.005)[a]	(1.08±0.08)[a]	(9.5±0.5)[b]	(0.109±0.003)[ab]	(0.158±0.014)[ab]	(0.173±0.019)[a]	(363±13)[b]
		p=0.809	p=0.736	p=0.018*	p=0.020*	p=0.197	p=1.000	p=0.024*
GA × 0		(0.215±0.003)[a]	(0.95±0.00)[a]	(6.8±0.0)[a]	(0.064±0.001)[a]	(0.157±0.005)[a]	(0.199±0.001)[a]	(95±3)[a]
GA × 0.75		(0.218±0.003)[a]	(1.17±0.17)[a]	(9.6±0.5)[b]	(0.094±0.011)[b]	(0.164±0.015)[a]	(0.173±0.031)[a]	(368±78)[b]
GA × 1.5		(0.218±0.003)[a]	(0.91±0.05)[a]	(8.6±0.7)[ab]	(0.084±0.006)[ab]	(0.142±0.003)[a]	(0.187±0.011)[a]	(435±9)[b]

BF=before frying, AF=after frying, CMC=carboxymethyl cellulose, GA=gum arabic, OLE=olive leaves extract, NLE=nettle leaves extract, nd=not determined, PT=polymer type, ET=extract type, EC=extract concentration (%). Results for the uncoated sample are expressed as mean±SD and results for coated samples are expressed as mean±SE. Values with different letters within column are statistically different at p≤0.05.

SUPPLEMENTARY MATERIAL:

Fig. S1. Photos of potato dipping and frying