Hydrocolloids of Date Pits Used as Edible Coating to Reduce Oil Uptake in Potato Strips During Deep-Fat Frying

Rasha M.A. Mousa
Home Economic Dept., Fac. of Specific Education, Assiut University,
71516- Assiut, Egypt

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ABSTRACT

In the current study, a rapid and simple method including the use of aqueous solution containing hydrocolloids and phenolics extracted from date pits (HSDP) was used, for the first time, as a natural edible coating to reduce oil uptake in potato strips during deep-fat frying. The results indicated that HSDP solutions contained 8.2-17.9 g/kg hydrocolloids and 0.31-1.95 g/kg phenolics. Samples of coated potatoes were prepared by different HSDP concentrations (0.5-6%, w/v) followed with/without drying before deep-fat frying. Analysis of deep-fat fried samples indicated that 4% HSDP coating reduced oil uptake by 77.7% which is higher than that of other hitherto published reports. Texture and colour analysis showed adequate brittleness, crispiness and lightness of HSDP coated fries compared to common methyl cellulose coated fries. Sensory analysis reflected also that HSDP coating maintained the overall acceptability of potato products. Therefore, the proposed HSDP coating is a rapid, economic and easy-to-operate process at homes for preparing acceptable low-fat potato fries that widely used not only in our society but also all over the world.

Keywords: *Date pits, frying, hydrocolloids, oil uptake, potatoes, strips*

INTRODUCTION

Frying is one of the oldest cooking processes of food which makes numerous chemical changes for food products such as starch gelatinization, protein denaturation, surface browning, rapid water evaporation, and oil absorption. In fact, frying process involves two mass transfers in opposite directions within the material being fried: water and soluble materials escape from the core to the crust and the water in the crust evaporates and moves out of the food, whereas oil penetrates the product constituting up to 30% of the final product (USDA-ARS, 2000). Deep-fat frying is a widely used method for preparing foods by immersing them in the hot vegetable oil so that all flavours and juices are retained inside (Moyano *et al.*, 2002). Fried potato strips are popular deep fat fast-foods in many countries. One of the important quality attributes of fried potato products is the amount of oil content in these products. Fried potato strips with low oil content can have a hard and unfavourable texture. However, higher oil usage in fried potato products is not recommended which has become a health related issue mainly associated with obesity, high blood cholesterol, high blood pressure and heart diseases (Rosenheck, 2008). Today customers are looking for food products with lower oil contents and this is driving force for many recent works that are aiming at reducing the oil content of final products.

Edible coatings may become a simple good technology coupled with the most popular oil frying to reduce the oil absorption in fried potato strips (Hua *et al.*, 2015). An edible coating is a thin layer of edible material formed as a coating on a food product (Mahfoudhi *et al.*, 2012). The effectiveness of a coating is determined by its mechanical and barrier properties, which depend on its composition and microstructure. Hydrocolloids, which are starchy gum coatings, were used as multifunctional coating agents in food processing to improve functional properties such as viscosity, water binding capacity and emulsion stability (Whistler & BeMiller, 1993, Williams & Mittal, 1999). Regarding methodology to obtain edible coatings (Carmen *et al.*, 2011), in a first step, the hydrocolloids must be properly dissolved in water. In some cases, it is necessary to heat or adjust the pH of the hydrocolloids solution in order to dissolve them. Once the hydrocolloids were dissolved, it is possible to add other substances, like antimicrobials, antioxidants and colourants, in order to confer the desired functional property to the coating. Another possibility is the modification of hydrocolloid structure by crosslinking reaction, photocrosslinking, lipid addition, or reaction with polyvalent ions. Many researches have employed hydrocolloids as edible coatings to reduce oil content in fried potato strips such as pectin, sodium alginate, inulin, corn zein, gums, starch, sodium caseinate, soy protein isolate, vital wheat gluten, whey protein isolate and powdered cellulose or its derivatives (Feeney *et al.*, 1993, Garcia *et al.*, 2002, Holikar *et al.*, 2005, Carmen *et al.*, 2011). It was found that coating hydrocolloid agents such as proteins, fibers and carbohydrates led to the decrease of oil content by 14.5%, 20% and 24.8%, respectively (Aminlari *et al.*, 2005, Garmakhany *et al.*, 2008). The coating of potato fries by methyl cellulose (MC) is more effective that 40.6% decrease in oil uptake was achieved (Garcia *et al.*, 2002). In comparison with MC, pectin was relatively less used to prepare edible coating for fried chips (Albert & Mittal, 2002). Recently, the effect of single and multi-layers of hydrocolloids during frying of potato fries was studied (Garmakhany *et al.*, 2014). Among different gums that used in this study as a single layer coating, a mixture of pectin and carboxymethyl cellolse (CMC) or xanthan led to about 76% decrease in oil content. However, xanthan is not favourable because their solution have a high viscosity and cannot coat the products uniformly. Considering double and triple-layer coating, although they can reduce the oil uptake, but they not recommended for potato strips, because these coated products have high moisture content nor a tender texture. Therefore, a mixture of the most useful hydrocolloids such as MC and CMC in the presence of pectin and alginate is an effective edible coating for potato strips. All these cellulose derivatives are water soluble with good film-forming properties. Pectin is widely used in food systems to stabilize and to modify the rheology of food. Then, the production of a mixture of hydrocolloids using cheap, safe, and easily accessible agricultural wastes is a growing research interest.

Among the agricultural wastes, date pits are one of the best materials because they are inexpensive and abundantly available, specifically in Mediterranean countries (Al–Farsi & Lee, 2008). Since a large quantity of date pits is being produced as a waste material, approximately 825,000 tons of date pits are produced annually (FAO, 2007). Date pits are well-known as a source of hydrocolloids and phenolics. It was reported that date pits contained 22.5–80.2% dietary fiber or hydrocolloids and phenolics of 3102–4430 mg gallic acid equivalents/100 g (Al- Farsi *et al.*, 2007). The extraction of date pits in water (hydrocolloid solution of date pits, HSDP) was found to contain 1.53 g/100g hydrocolloids such as pectin, inulin and methyl cellulose (Hamada *et al.*, 2002). Moreover, 0.16 g/100g of phenolic compounds including protocatechuic, caffeic and ferulic acid were recorded in HSDP (Baliga *et al.*, 2011). It is well known that these phenolic compounds possess health benefits as antioxidants (Peterson & Dwyer, 1998), anti-carcinogenics and reduction of cardiovascular diseases (Mousa, 2015). Thus, it is considered important to increase the antioxidant intake in the human diet and one way of achieving this is by enriching food with phenolics. However, studies relating to the antioxidant activity of date seeds are limited. To the best of our knowledge, there are no reports dealt with HSDP as edible coating on decreasing oil uptake in potato strips during deep-fat frying.

In the current study, the utilization of the HSDP as a new cheap and safe source of hydrocolloids and phenolics would be of great interest to simply use as an edible coating for potato strips. Also, the influence of HSDP concentration on the oil uptake reduction in proposed potato strips was also investigated. The texture analysis, colour measurement and sensory evaluation of HSDP-coated potato fries and MC-coated strips (as a contrast) were also performed.

MATERIALS AND METHODS

Materials

The powder of date palm (*Phoenix Dactylifera L.*) pits was obtained from the local market in New Valley Governorate (Egypt). Palm oil was purchased from supermarket in Assiut Governorate (Egypt). Methyl cellulose and ferulic acid were purchased from Merck Company (Germany). All other chemicals were obtained from Sigma–Aldrich Co. Ltd. (St. Louis, MO, USA) unless otherwise specified.

Methods

Chemical analysis of date pits powder

The standard methods of AOAC (1995) were employed for proximate analysis including moisture, crude protein, crude fat and ash contents of date pits powder. Nitrogen free extract (NFE) was calculated by difference. Soluble and insoluble fiber contents were determined by enzymatic gravimetric method (AOAC, 1995). Triplicate samples were gelatinized with heat stable α-amylase, then enzymatically digested with protease and amyloglucosidase to remove the protein and starch. After enzymatic hydrolysis, the residues were recovered by centrifugation and washed with distilled water (twice), alcohol 95% (twice), and acetone (once). Finally, residues are dried and weighed. Corrections are made during the determination of protein and ash. Insoluble fiber (IF) content is calculated using the following formula: IF (g/ 100g)= (Residue−(Protein + Ash))×100. After enzymatic attack, 4 volumes of 95% ethanol were added to the supernatant to precipitate inulin. The precipitate, collected by centrifugation, was washed successively with 75% ethanol, 95% ethanol, and acetone. The dried residue was weighed. Corrections are made during the determination of protein and ash. Soluble fiber (SF) content is determined from the following formula: SF (g/ 100g)= [(Residue)−(Protein + Ashes)]×100.

The main elements including sodium, potassium, manganese, magnesium, calcium, iron, copper, zinc and phosphorus were determined based on the methods published in AOAC (1995). The samples were firstly digested using a mixture of nitric acid and perchloric acid (HNO_3, $HClO_4$, 2:1 v/v). After the complete digestion of samples, the amounts of iron, copper, calcium, magnesium, manganese and phosphorous were determined using atomic absorption spectrometry (AAS) (Agilent Technologies, California, USA). Sodium and potassium were determined by flame photometer (Jenway, UK). All measurements were repeated three times and the presented results are the mean values.

Determination of hydrocolloids and phenolics in hydrocolloid solution extracted from date pits powder

The hydrocolloid solution of date pits (HSDP) was easily prepared by suspending the appropriate amount of date pits powder in water and stir the solution for 3 min in electric grinder (Moulinex-700 W, France). Different concentrations of 0.5% w/v (HSDP1), 1% w/v (HSDP2), 2% w/v (HSDP3), 4% w/v (HSDP4) and 6% w/v (HSDP5) were prepared. These HSDP solutions were collected in glass tubes and stored at 4 °C until further uses. The content of total hydrocolloids and total phenolics in different HSDP solutions were measured by AOAC (1995) and Box (1983) methods, respectively. Pectin, inulin and methyl cellulose contents were measured by Hamada *et al.* (2002). Phenolic acids (gallic acid, protocatechuic acid, p-hydroxybenzoic acid, vanillic acid, caffeic acid, p-coumaric acid, ferulic acid, m-coumaric and o-coumaric acid) were determined according to the method of Alasalvar *et al.* (2005).

Preparation of coated potato strips and their frying

Potatoes obtained from a local market were firstly washed by water, then hand-peeled, cut with a cutter into 1cm × 1cm × 7cm strips, and were submerged for 5 min in HSDP solutions of 0.5% (HSDP1), 1% (HSDP2), 2% (HSDP3), 4% (HSDP4) and 6% (HSDP5) at room temperature. Other potato strips (HSDP 6→10) were prepared in the same concentrations of HSDP followed by drying for 10 min prior to frying (Chiou *et al.*, 2005). Two control samples C1 and C2 were prepared by immersing potato strips in water without drying and with drying prior to frying, respectively. For a comparison with a reference sample, reference potato strips coated by methyl cellulose (MC) were prepared by immersing them in aqueous solution of MC (1%, w/v) under the same aforementioned conditions. The used 1% of MC is the optimum one as reported in the previous study (Garmakhany *et al.*, 2014).

Frying of the above prepared HSDP-coated potato strips was performed in a temperature-controlled deep-fryer apparatus (GIRMI, Viterbo, Italy). Palm oil, which is mostly used to fry foods like potatoes (Pedreschi & Moyano, 2009), was used in the current work. The oil was preheated to the processing temperature (180°C, as usual in home and restaurants) prior to frying and replaced with fresh oil after each batch. Each batch of potato strips were fried in the preheated palm oil separately for 5 min with flipping from side to side every 1 min. The proportion of food to oil was constantly 1:1.25 (weight/oil). The fried potato strips were subsequently shaken in aluminum basket to drain off the excessive oil. The fried strips were allowed to cool at room temperature and analyzed for water loss and oil uptake as described below. All experiments were run in triplicate and the measured values are the average of the obtained results.

Determination of water loss

Firstly, water content for the HSDP-coated potato strips were determined on dried basis before and after frying process by following the procedure of AOAC (2005). Samples were placed in metal dishes and dried in a forced-air oven at 105 °C to a constant weight. Then, the water loss % was calculated based on the following equation:

$$\%\text{Water loss (WL)} = (WC_{\text{before frying}} - WC_{\text{after frying}} / WC_{\text{before frying}}) \times 100$$

The decrease in water loss due to coating was also measured by the following equation:

$$\text{Decrease in water loss due to coating} = (WL_c - WL_s/WL_c) \times 100$$

Where WL_c and WL_s are the water loss of the non-coated control samples and the water loss of HSDP-coated samples, respectively. All results of samples were expressed as percentage of original samples (w/w).

Determination of oil uptake

The fat content (FC) of potato strips was determined on dried basis for the HSDP-coated potato strips by using continuous Soxhlet extractions in hexane (AOAC, 2005). Then, the oil uptake was calculated by the following equation (Garmakhany *et al.*, 2014):

$$\text{Oil uptake (OU)} = \frac{(FC_{\text{after frying}} \times W_{\text{after frying}}) - (FC_{\text{before frying}} \times W_{\text{before frying}})}{\text{dry weight}} \times 100$$

Furthermore, the decrease in oil uptake due to coating was measured by the following equation:

$$\text{Decrease in oil uptake due to coating} = (OU_c - OU_s/OU_c) \times 100$$

Where OU_c and OU_s are the oil uptake of the non-coated control samples and the oil uptake of HSDP-coated samples, respectively. All results of samples were expressed as percentage of original samples (w/w).

Texture Analysis

The texture of studied coated potato strips was analyzed using a texture analyzer (TA-XT Plus, Texture Technologies, USA). A 2 mm cylinder stainless probe (Part Code. P/2) was used to measure force in compression mode, which depicts the force-distance plot of fried potato strips. Measurement settings: test speed = 1 mm/s, pre-test speed= 2 mm/s, post-test speed= 10 mm/s, distance= 5 mm and trigger force= 20 g. All the analyses were performed with at least three samples per batch.

Colour analysis

The colour of studied coated potatoes was measured with a digital colourimeter (CR-400, Minolta-Konica Sensing Inc., Osaka, Japan) using CIE Lab colour scale L^* (lightness), a^* (redness) and b^* (yellowness). Triplicate readings were carried out at 25 °C on each three equidistant locations of each strip (for both sides) and the mean value was recorded. Colour difference (Hunter ΔE) is expressed as:

$$\Delta E = \sqrt{(L^* - L_c^*)^2 + (a^* - a_c^*)^2 + (b^* - b_c^*)^2}$$

where the subscript c represents the L^*, a^*, and b^* values of the coated strips. The colour of non-coated (control) strips was designated as a reference.

Sensory analysis

The proposed different types of HSDP coated potato strips were subjected to sensory evaluation by 30 trained assessors. All of them are free from cold or sinus problem during the period of evaluation. Panelists were called for sensory evaluation at a time under "daylight" illumination and in isolated booths. Information on evaluation techniques used was presented to the panelists before the actual sensory test. Samples were fried 30 min before sensory evaluation and kept warm in a warmer plate until being evaluated. Samples (3 of each batch) were served in paper plates identified by random three digits codes. Care was taken to maintain the sensory environment at 25°C. The panelists first evaluated the control non-coated potato strips that had not been dealt with HSDP followed by other HSDP-coated strips. Panelists were asked to assess their degree of liking of the samples on paper ballot with a nine point hedonic rating scale, where (9) denotes like extremely and (1) denotes dislike extremely. The panelists observed the samples in terms of six sensory attributes colour, appearance, aroma, texture, taste and overall acceptability. They allowed swallowing samples and they instructed to clean their palate with water before tasting each sample.

Statistical Analysis

Values were expressed as means ± Standard deviation. Analysis of variance (ANOVA) was carried out using Minitab statistical software (USA) to determine the significant difference among treatments at $P < 0.05$.

RESULTS AND DISCUSSION

Chemical analysis of date pits powder

The chemical analysis of date pits powder as cited in Table (1) showed that the mean values of crude protein, crude fat, ash content and moisture content were 6.55±0.42, 9.2±0.11, 1.34±0.25 and 3.71±0.21g/100g, respectively. As well, the soluble fiber and insoluble fiber amounts were found to be 1.26±0.31 and 5.99±0.31%, respectively. The NFE content was calculated by difference to be 71.95±0.25 g/100g. Furthermore, the mineral analysis of date pits powder (Table 1) indicated that the amounts of calcium, magnesium, potassium, sodium and phosphorus are 0.40±0.20, 0.90±0.14, 0.300±0.20, 0.20±0.15 and 0.180±0.16 mg/100 g, respectively. Moreover, the amounts of iron, copper, zinc and manganese are measured and found to be 175.08±0.30, 4.85±0.06, 22.0±0.19 and 11.02±0.11 ppm. These results are in a good agreement with those reported by Hossain *et al.* (2014). As well, Abdel Nabey (1999) analyzed the chemical composition and the physico-chemical characteristics of 6 Egyptian date palm cultivars giving values very close to the current work.

Table 1: The proximate chemical composition including soluble and insoluble fibers as well as mineral contents of date pits powder

Componant (%)	Value
Crude protein	6.55 ± 0.42
Crude fat	9.20 ± 0.11
Ash content	1.34 ± 0.25
Moisture content	3.71 ± 0.21
Soluble fiber	1.26 ± 0.31
Insoluble fiber	5.99 ± 0.31
Nitrogen free extract (NFE)	71.95 ± 0.25
Macroelements (mg/100g)	
Calcium	0.40 ± 0.20
Magnesium	0.90 ± 0.14
Potassium	0.300 ± 0.20
Sodium	0.20 ± 0.15
Phosphorus	0.180 ± 0.16
Microelements (ppm)	
Iron	175.08 ± 0.30
Cupper	4.85 ± 0.06
Zinc	22.00 ± 0.19
Manganese	11.02 ± 0.11

Determination of hydrocolloids and phenolics in HSDP solutions

Since the concentration of hydrocolloids is one of the most effective parameter for the efficiency of edible coating to reduce oil absorption in potato strips, in the current work, the total amount of soluble hydrocolloids in different HSDP solutions of 0.5% w/v (HSDP1), 1% w/v (HSDP2), 2% w/v (HSDP3), 4% w/v (HSDP4) and 6% w/v (HSDP5) was investigated. The total amount of phenolics in these solutions was also quantified. Table (2) shows the total amounts of hydrocolloids and phenolics in these solutions. It is obviously that the content of hydrocolloids was markedly increased from 8.2 to 17.5 g/kg by increasing HSDP concentrations from 0.5 to 4%, respectively. Whereas further increasing of HSDP concentrations up to 6% did not give any significant increment in the amount of hydrocolloids. This is in consistent with mass transfer principles; the driving force during mass transfer is the concentration gradient between the solid (hydrocolloids) and the water, which is greater when a higher solid amount is used till saturation limit. The same observation was obtained in the determination of phenolic content in these HSDP solutions. They were markedly increased from 0.31 to 1.82 g/kg by increasing HSDP amount from 0.5 to 4%, respectively. Similar results about the effect of solvent to solid ratio on the extraction of phenolic compounds were reported by Cacace & Mazza (2003). Furthermore, the results in Table (2) indicated that the HSDP solutions contain pectin, inulin and methyl cellulose at the amount of 1.50-1.65 g/100 g date pits. The highest amounts were achieved in HSDP4 solution which further remained without any significant increasing in HSDP5 solution. These results are in accordance with those obtained by Al-Farsi & Lee (2008). Moreover, a nine of phenolic acids were detected in HSDP solutions (Table 2), of which four consisted of hydroxylated derivatives of benzoic acid (gallic acid, protocatechuic acid, p-hydroxybenzoic acid and vanillic acid) and five were cinnamic acid derivatives (caffeic acid, p-coumaric acid, ferulic acid, m-coumaric and o-coumaric acid). Among the identified phenolic acids in HSDP4 solution, protocatechuic (71.71 mg/ 100g), vanillic (12.92 mg/100g), caffeic (40.81 mg/100g) and ferulic acid (12.94 mg/100g) were the major phenolic acids. These results are in accordance with those obtained by Al-Farsi & Lee (2008). Therefore, the current results confirmed that the amounts of hydrocolloids

Table 2: Hydrocolloid and phenolic contents of different HSDP solutions

	HSDP1	HSDP2	HSDP3	HSDP4	HSDP5
Pectin* (g/100 g)	1.50± 0.44[a]	1.54± 0.15[b]	1.58± 0.07[c]	1.62± 0.05[d]	1.63± 0.08[d]
Inulin* (g/100 g)	1.52± 0.04[a]	1.54± 0.16[b]	1.57± 0.07[c]	1.60± 0.12[d]	1.60± 0.09[d]
MC* (g/100 g)	1.51± 0.34[a]	1.55± 0.14[b]	1.60± 0.05[c]	1.65± 0.11[d]	1.65± 0.14[d]
Total Hydrocolloids (g/kg)**	8.2± 0.31[a]	11.4± 0.11[b]	14.7± 0.44[c]	17.5± 0.23[d]	17.9± 0.41[d]
Phenolic acids***					
Gallic acid (mg/100g)	0.31± 0.08[a]	0.54± 0.05[b]	0.83± 0.11[c]	1.07± 0.12[d]	1.09± 0.02[d]
Protocatechuic acid (mg/100g)	17.13± 1.04[a]	35.38± 0.32[b]	54.77± 0.26[c]	71.71± 1.09[d]	72.90± 1.01[d]
p-hydroxybenzoic acid (mg/100g)	3.02± 0.54[a]	4.74± 0.06[b]	6.97± 0.15[c]	9.04± 0.13[d]	9.07± 0.06[d]
Vanillic (mg/100g)	3.22± 1.06[a]	6.33± 0.13[b]	9.14± 1.06[c]	12.92± 1.18[d]	13.20± 0.04[d]
Caffeic acid (mg/100g)	10.12± 0.06[a]	20.13± 0.09[b]	30.54± 0.62[c]	40.81± 0.09[d]	40.95± 0.14[d]
Ferulic acid (mg/100g)	3.94± 1.38[a]	6.11± 0.23[b]	8.99± 0.62[c]	12.94± 0.05[d]	13.01± 0.23[d]
p-coumaric (mg/100g)	1.14± 0.08[a]	2.54± 0.09[b]	3.79± 0.02[c]	5.74± 0.16[d]	5.97± 0.46[d]
m-coumaric (mg/100g)	1.11± 0.43[a]	2.46± 0.11[b]	3.91± 0.12[c]	5.84± 0.08[d]	6.07± 0.17[d]
o-coumaric (mg/100g)	0.01± 0.04[a]	0.02± 0.10[b]	0.03± 0.02[c]	0.04± 0.81[d]	0.04± 0.03[d]
Total Phenolics** (g/kg)**	0.31± 0.03[a]	0.84± 0.05[b]	1.34± 0.04[c]	1.82± 0.03[d]	1.95± 0.02[d]

Values are mean ± SD of three determinations (n=3). Mean ± SD followed by the same letter, within a row, are not significantly different (P>0.05).

* Pectin, inulin and methyl cellulose contents were measured by Hamada *et al.* (2002);

** Total hydrocolloids was measured by AOAC (1995); ***Phenolic acids were determined according to the method of Alasalvar *et al.* (2005).

**** Total phenolics was measured by Box (1983).

and phenolics in all HSDP solutions, in particular HSDP4 solution, could be enough to make a sense in the formation of edible coatings with antioxidant properties.

Contents of water and oil in non-coated potato strips

The amounts of water and fat in the non-dried non-coated control samples of potato strips (C1) and the dried non-coated control samples (C2) were determined before and after the frying process. It was found that the control samples (C1) before frying had a water content of 72.8 ± 1.2% (w/w) and a fat content of 6.5 ± 2.0% (w/w). After frying, the water content decreased down to 40.8 ± 1.2% (w/w) and the fat content increased up to 31.2 ± 1.0% (w/w). The pre-drying process of control samples (C2) did not give any significant difference on the contents of water (41.1 ± 1.4%) and fat (29.6 ± 1.0%) after frying. It is obviously noticed that the total content of water and fat after frying was almost equal to that before frying. This phenomenon was in an agreement with the mass balance criterion proposed by Pinthus *et al.* (1993), in which the mass of water evaporated was considered nearly equal to the mass of fat absorbed during frying, because the vapour left voids for the fat to enter. Likewise, the oil penetration depth was characterized to be close to the evaporation front.

The oil uptake and water loss in coated potato strips

The data of performed experiments revealed that the increase of HSDP concentrations resulted in significant changes (P<0.05) of both fat content and water content among all HSDP-coatings. For example, the water content of HSDP1 and HSDP4 were 41.2 ± 2.1% and 70.2 ± 1.5%, respectively. The corresponding fat content markedly changed from 31.0 ± 1.7% (HSDP1) to 7.9 ± 2.5% (HSDP4). Further increasing of hydrocolloids (HSDP5 samples) did not make any significant change compared to HSDP4 samples. As shown in Table (3), the oil uptake and water loss were quantified in the HSDP coated potato strips (HSDP 1→5 samples) and as well, in the pre-dried HSDP coated potato strips (HSDP 6→10 samples). The non-pre-dried coated samples (HSDP 2→5) had a lower oil uptake than non-coated sample (C1) which was significantly different (P<0.05). These results suggested that 4% HSDP solution was appropriate to reduce the oil content of potato strips. However, the results of sample HSDP1 are very close to the control sample (C1) which means that 0.5% HSDP solution contains low hydrocolloid amount which is not enough to induce a thermal-gelation. In the case of the pre-dried coated potato products (HSDP 6→10 samples), the oil uptake and water loss values were a little bit higher than that of non-pre-dried coated potatoes. When pre-dried samples were subjected to frying, fat can easily enter into capillary pores ever occupied by water. As a result, the oil uptake of pre-dried HSDP-coated strips was slightly high. Therefore, the pre-drying process is not recommended in order to simplify the proposed technology application in home or restaurant.

The decrease in oil uptake and water loss of potato strips due to HSDP coating were also calculated as depicted in Table (3). The maximum decrease in oil uptake due to HSDP coating was achieved by HSDP5 samples (81.7 ± 1.0%) which is very close to the HSDP4 (77.7 ± 1.3%). Moreover, the decrease of water loss during frying by HSDP4 was 85.5 ± 1.6% which is very close to the maximum decrease in water loss 89.3 ± 0.3% by HSDP10. Hydrocolloids which can be placed on the external surface of potato strips act as a barrier to moisture removal during frying and so, reduced the water loss of potato strips. These results are in agreement with the results reported by Hua *et al.* (2015). Also, Garmakhany *et al.* (2014) stated that a mixture of pectin and CMC or xanthan could reduce the oil absorption up to 76%. However, xanthan is not favourable because their solution have a high viscosity and cannot coat the products uniformly.

Methyl cellulose (MC) is a representative cellulose derivative and has been used to make edible coating for fried strips. During frying, moisture was gradually evaporated and the hydrophobic association of MC chains was enhanced resulting in thermal induced gelation. In order to make an evaluation on HSDP-coating, further comparison was done with MC-coated strips. These samples were prepared by submersing potato strips in 1% (w/w) MC and 0.5% (w/w) calcium chloride followed by other practical preparations as described in the experimental section. As shown in Table (3), by the comparison between MC-coated strips and HSDP-coated strips, it is obvious that HSDP4/HSDP5-coated strips showed significantly ($P<0.05$) higher reduction in water loss and oil uptake. This could be due to the mixing of several hydrocolloids in

Table 3: Water loss and oil uptake of HSDP-coated potato strips and the use of MC-coating as a comparable product

Sample	Water content before frying % (w/w)	Water content after frying % (w/w)	Water loss* % (w/w)	Decrease in water loss due to coating* % (w/w)	Fat content before frying % (w/w)	Fat content after frying % (w/w)	Oil uptake* % (w/w)	Decrease in oil uptake due to coating* % (w/w)
C1	72.8± 1.2^{a}	40.8± 1.2^{a}	44.0± 0.3^{a}	------	6.5± 2.0^{a}	31.2± 1.0^{a}	79.2± 0.2^{a}	-------
C2	73.3± 1.0^{a}	41.1± 1.4^{a}	43.9± 0.2^{a}	------	6.7± 1.2^{a}	29.6± 1.0^{a}	79.1± 0.1^{a}	-------
HSDP1	73.3± 1.1^{a}	41.2± 2.1^{a}	43.8± 0.1^{a}	0.5± 0.1^{a}	6.6± 2.0^{a}	31.0± 1.7^{a}	79.0± 0.1^{a}	0.3± 0.1^{a}
HSDP2	75.0± 1.4^{b}	44.7± 3.1^{b}	40.4± 0.2^{b}	8.1± 0.3^{b}	6.8± 1.7^{a}	27.1± 0.8^{a}	76.0± 0.3^{a}	4.0± 0.4^{a}
HSDP3	75.0± 1.0^{b}	59.5± 1.1^{c}	20.7± 0.2^{c}	52.9± 1.3^{c}	7.8± 1.6^{b}	11.4± 2.1^{b}	42.9± 0.2^{b}	45.8± 0.3^{c}
HSDP4	75.0± 1.7^{b}	70.2± 1.5^{d}	6.4± 0.1^{d}	85.5± 1.6^{d}	6.2± 1.9^{a}	7.9± 2.5^{c}	17.7± 0.2^{c}	77.7± 0.3^{b}
HSDP5	76.6± 1.3^{b}	72.3± 1.4^{d}	5.6± 0.1^{d}	87.3± 0.8^{d}	5.9± 1.7^{c}	7.6± 1.5^{c}	14.5± 0.1^{c}	81.7± 1.5^{b}
HSDP6	74.5± 1.1^{b}	42.1± 1.4^{a}	43.5± 0.3^{a}	1.1± 0.3^{a}	6.5± 1.4^{a}	31.2± 1.0^{a}	79.2± 0.1^{a}	0.0± 0.0
HSDP7	75.0± 1.3^{b}	45.6± 1.3^{b}	39.2± 0.2^{b}	10.9± 0.9^{b}	6.8± 1.8^{a}	27.5± 1.6^{a}	77.1± 0.1^{a}	2.7± 0.4^{a}
HSDP8	75.0± 1.2^{b}	60.3± 1.0^{c}	19.6± 0.1^{c}	55.5± 1.6^{c}	7.8± 1.5^{b}	11.9± 1.1^{b}	44.8± 0.1^{ab}	43.4± 0.3^{b}
HSDP9	75.0± 2.0^{b}	70.9± 2.6^{d}	5.5± 0.1^{d}	87.5± 2.1^{d}	6.2± 1.5^{a}	8.1± 0.5^{c}	18.1± 0.1^{c}	77.1± 0.6^{b}
HSDP10	77.3± 2.1^{c}	73.7± 2.4^{d}	4.7± 0.4^{d}	89.3± 0.3^{d}	5.9± 2.3^{c}	7.8± 1.9^{c}	14.9± 0.1^{c}	81.2± 1.8^{b}
MC-coated	75.1± 2.1^{b}	52.1± 1.9^{a}	30.6± 0.1^{a}	30.5± 0.4^{a}	7.1± 2.0^{d}	19.3± 1.5^{a}	59.5± 0.4^{a}	24.9± 0.6^{a}

Values are mean ± SD of three determinations (n=3). Different letters within a column indicate significantly different values ($P<0.05$).

* They were calculated by the equations reported in the materials and methods section.

one solution could achieve better reduction of oil uptake in potato strips. These results are in good agreement with Garmakhany *et al.* (2014). However, the reproducibility of results of oil uptake in HSDP4 samples with RSD<0.5 is better than those by others. Therefore, HSDP4-coating could be used as an effective edible coating for the reduction of oil uptake (about 77.7%) with reliable results.

Texture analysis

Brittleness and crispiness are important textural parameters for fried coated potato strips. A general rule is that a crispy product's initial resistance to probe builds faster than non-crispy products. The initial slope of a texture plot is thus a good measure of crispiness. A more brittle sample can present a shorted deformation distance (time) when it is broken. The results of strips with the control and the various HSDP coatings were depicted in Figs. (1 & 2). The non-coated control samples (C1 and C2) presented a Tootsie Roll, which exhibited a firm rounded curves as shown in Fig. (1). The roundness of the curve suggested that the non-coated strips were more pliable than brittle and perhaps more firm than crisp. Once the product compresses, its crispness passes and it is relatively pliable before it finally breaks.

In the case of HSDP-coated potato strips, the brittleness reduced when HSDP concentration increased, since the breaking time was progressively prolonged as shown in Fig. (2). The decrease of crispiness of HSDP-coated strips was indicated by the curve slope. When the amounts of date pits hydrocolloids increased, the brittleness and crispiness of strips considerably increased. The reason can be the higher water content retained inside, which reduced pliability of strips. The curve shape of HSDP4 (Fig. 2, curve d) was similar to that of non-coated control samples except for missing of Tootsie Roll. The strips treated with HSDP5 had the highest brittleness and crispiness (Fig. 2, curve e), which means a high initial resistance due to the formation of hard hydrocolloids crust. In addition, high water content has inhibited the interaction between starch, protein and lipid, resulting in loss of pliability. The pre-dried HSDP coated strips did not show any significant changes compared to non-pre-dried HSDP samples (P >0.05).

Colour analysis

Colour is an important attribute of potato strips coating. Colour change during frying is the result of Maillard reaction that mainly depends on the content of reducing sugars and amino group-containing compounds resulting in colored melanoidins formation (Bal *et al.*, 2011). The colour components (L^*: lightness, a^*: redness, b^*: yellowness) and colour change (ΔE) of non-coated and coated potato strips were illustrated in Table (4). The component a^* of HSDP-coated potato strips with different hydrocolloids concentrations with/without pre-drying process (HSDP1→10) showed slightly change in comparison with non-coated strips (C1 and C2) and MC-coated strips. This small change was due to the short frying time as browning reaction is highly time-dependent. The other colour components (L^*, b^*) were significantly affected ($P<0.05$) by the coating process. The HSDP coated strips has a significantly lighter colour (higher L^* value) than the

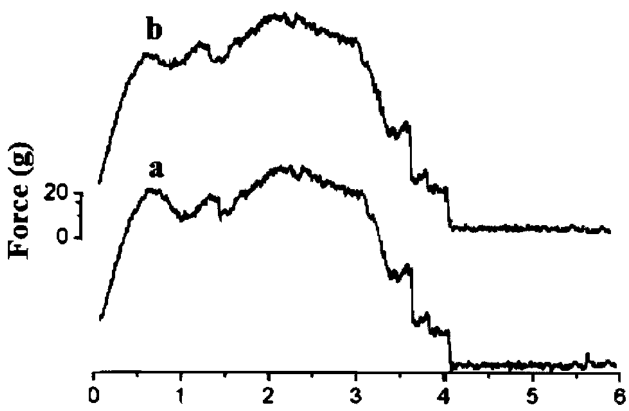

Fig. 1: Texture analysis of non-coated potato strips without pre-drying (a) and with pre-drying (b)

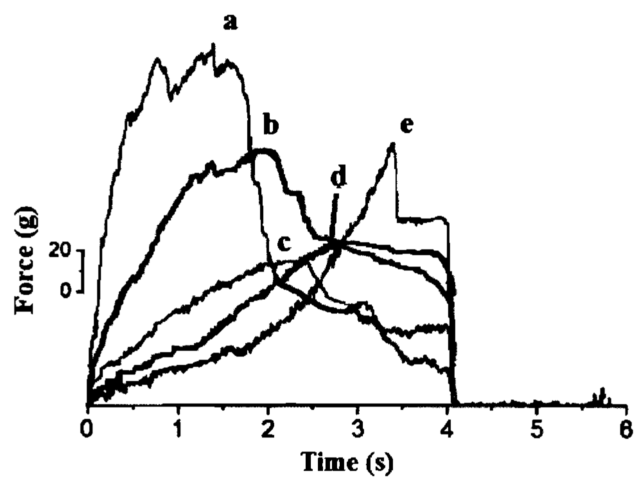

Fig. 2: Texture analysis of potato strips coated with various HCDP concentrations without pre-drying: a) HSDP1; b) HSDP2; c) HSDP3; d) HSDP4 and e) HSDP5

non-coated strips, while MC-coated strips exhibited considerably lower L* (P < 0.05) as depicted in Table (4). Furthermore, the lightness value (L*) increased gradually from 71.5±1.1 to 90.3±1.9 by increasing the HSDP concentrations. The pre-dried HSDP samples (HSDP 6→10) showed very slightly changes in the values of L* compared to non-pre-dried samples. This phenomenon indicated that HSDP coatings underwent the Maillard reaction in a lower degree in comparison with MC. One reason can be the steric hindrance due to crosslinking of hydrocolloids in HSDP solution or the presence of phenolic acids in the same solution, whereby some reducing terminals were buried inside or shielded and consequently inaccessible for Maillard reaction. This also fosters the researcher to use a solution containing several hydrocolloids. In addition, high water retained could inhibit the interaction between amino groups and sugars. The golden surface colour developed during frying is primarily related to yellowness b*. The yellowness (b*) values of the fried strips coated with HSDP was significantly higher (P<0.05) than those non-coated samples, while they had very close values for that MC-coated strips (P>0.05) as shown in Table (4). Furthermore, the colour difference ΔE were also calculated to be ranged from 24.1 to 44.3 due to the difference in HSDP concentrations compared to 27.6 for MC-coated strips.

Table 4: Colour components (L*: lightness, a*: redness, b*: yellowness, ΔE) of studied potato strips

Sample	L*	a*	b*	ΔE
C1	60.8± 1.0ᵃ	4.5± 0.8ᵃ	18.9± 1.1ᵃ	-----
C2	61.1± 1.4ᵃ	4.3± 0.5ᵃ	18.1± 1.0ᵃ	-----
HSDP1	71.5± 1.1ᶜ	4.8± 0.4ᵃ	41.3± 1.0ᵇ	35.5
HSDP2	74.7± 2.3ᶜ	4.4± 0.2ᵃ	48.3± 0.9ᵇ	32.5
HSDP3	81.5± 1.5ᶜ	5.7± 0.2ᵃ	49.1± 0.3ᵇ	36.6
HSDP4	88.2± 1.0ᶜ	5.4± 0.1ᵃ	50.1± 0.8ᵇ	41.5
HSDP5	90.3± 1.9ᶜ	5.6± 0.1ᵃ	51.9± 1.0ᵇ	44.3
HSDP6	70.9± 0.9ᶜ	4.5± 0.3ᵃ	40.8± 1.2ᵇ	24.1
HSDP7	73.4± 1.3ᶜ	3.9± 0.2ᵃ	44.8± 0.9ᵇ	29.4
HSDP8	80.1± 1.3ᶜ	4.6± 0.1ᵃ	48.1± 0.8ᵇ	35.5
HSDP9	87.1± 1.5ᶜ	5.5± 0.1ᵃ	49.6± 1.8ᵇ	40.9
HSDP10	90.8± 1.0ᶜ	4.7± 0.2ᵃ	50.9± 1.2ᵇ	44.3
MC-coated	50.1± 1.3ᵇ	4.5± 0.4ᵃ	44.3± 1.3ᵇ	27.6

Values are mean ± SD of three determinations (n=3). Different letters within a column indicate significantly different values (P<0.05).

Sensory evaluation

Results of sensory evaluation were presented in Table (5). The non-coated potato strips had the highest scores in all attributes and overall acceptance. The overall acceptance of HSDP-coated potato strips was significantly higher (P<0.05) than that of MC-coated strips. Furthermore, the overall acceptance between HSDP-coated fries was non-significant (P>0.05). The negative influence of edible coatings on sensory attributes of fried strips compared to non-coated strips can be explained as

Table 5: Sensory characteristics of the studied potato strips.

Sample	Colour	Appearance	Aroma	Texture	Taste	Overall Acceptability
C1	7.4± 1.0ᵃ	7.6± 0.9ᵃ	6.7± 1.6ᵃ	6.9± 1.3ᵃ	7.0± 1.0ᵃ	7.4± 1.1ᵃ
C2	7.5± 1.4ᵃ	7.5± 0.4ᵃ	6.7±1.3ᵃ	6.8± 1.8ᵃ	7.0± 1.3ᵃ	7.3± 1.0ᵃ
HSDP1	6.6± 1.2ᶜ	6.5± 1.3ᵇ	6.5±1.1ᵃ	6.0± 1.0ᵃᵇ	6.6± 1.3ᵃ	6.6± 1.7ᵇ
HSDP2	6.1± 1.1ᶜ	6.6± 1.0ᵇ	6.4±1.0ᵃ	6.1± 0.9ᵃᵇ	6.7± 1.8ᵃ	6.6± 1.3ᵇ
HSDP3	5.7± 1.0ᵇ	6.6± 0.9ᵇ	6.4±0.9ᵃ	6.0± 1.7ᵃᵇ	6.6± 1.0ᵃ	6.7± 1.0ᵇ
HSDP4	5.5± 1.6ᵇ	6.7± 1.7ᵇ	6.3±1.5ᵃ	6.3± 1.1ᵃᵇ	6.5± 1.5ᵃ	6.7± 1.3ᵇ
HSDP5	5.4± 1.8ᵇ	6.8± 1.3ᵇ	6.2±1.3ᵃ	6.2± 1.2ᵃᵇ	6.6± 1.0ᵃ	6.5± 1.8ᵇ
HSDP6	6.5± 1.0ᶜ	6.5± 1.1ᵇ	6.4±1.0ᵃ	6.0± 0.9ᵃᵇ	6.4± 1.2ᵃ	6.6± 1.5ᵇ
HSDP7	6.1± 1.1ᶜ	6.5± 0.8ᵇ	6.3±1.4ᵃ	6.1± 0.9ᵃᵇ	6.6± 0.7ᵃ	6.7± 1.8ᵇ
HSDP8	5.3± 1.0ᵇ	6.6± 1.9ᵇ	6.4±1.9ᵃ	6.2± 1.7ᵃᵇ	6.7± 1.5ᵃ	6.6± 0.9ᵇ
HSDP9	5.2± 1.1ᵇ	6.8± 1.0ᵇ	6.4±1.3ᵃ	6.2± 1.6ᵃᵇ	6.4± 1.4ᵃ	6.7± 0.9ᵇ
HSDP10	5.3± 1.2ᵇ	6.7± 1.3ᵇ	6.3±1.0ᵃ	6.3± 1.2ᵃᵇ	6.6± 1.0ᵃ	6.8± 1.3ᵇ
MC-coated	5.7± 1.8ᵇ	6.5± 1.6ᵇ	5.4±1.2ᵇ	5.7± 1.3ᵇ	5.7± 1.6ᵇ	5.7± 1.5ᶜ

Values are mean ± SD of three determinations (n=3). Different letters within a column indicate significantly different values (P<0.05).

follows: (1) During frying, HSDP and starch could undergo chemical reactions in varying degrees resulting in different colour change; (2) The edible coatings can retard the starch gelatinization and retrogradation leading to different crust appearance of fried strips; (3) The edible coatings have retained more moisture and less oil inside the fried strips, thereby generating different mouth feeling.

CONCLUSION

In the present study, an aqueous solution of date pits (HSDP) containing hydrocolloids and phenolics was used, for the first time, to prepare an edible coating for potato strips. The results indicated that the total contents of hydrocolloids and phenolics were markedly increased from 8.2 to 17.5 g/kg and from 0.31 to 1.82 g/kg, respectively by increasing HSDP concentrations from 0.5 to 4.0 % (w/v). The maximum reduction of oil uptake by 77.7±1.3% and water loss by 85.5 ± 1.6% with acceptable repeatability of the results was achieved by 4% HSDP-coating. This could be the water barrier properties of HSDP coating under common frying conditions without drying process. The sensory attributes of HSDP-coated fried strips were somewhat worse than non-coated strips, however, the HSDP-coated products were also overall acceptable. Preparation of HSDP coating is economic and easy-to-operate in homes as the pre-treatment for preparing low-fat potato fries. Besides this economic feature, the proposed methodology provided fried coated potato strips with appreciated tint and texture properties.

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استخدام محلول المواد الغروية المستخلصة من مسحوق نوى البلح كمادة مغلفة قابلة للأكل لخفض كمية الزيت الممتص بالبطاطس أثناء عملية القلى العميق

رشا موسى أحمد موسى

قسم الاقتصاد المنزلى - كلية التربية النوعية - جامعة أسيوط - مصر

استخدم في هذه الدراسة لأول مرة طريقة بسيطة وسريعة للتقليل من امتصاص الزيت أثناء عملية القلى العميق للبطاطس باستخدام مسحوق نوى البلح المتوفر بالسوق المحلى والمحتوى محلوله فى الماء على مواد غروية. وتعتمد هذه الطريقة على الغمر الكامل و السريع للبطاطس فى محلول المواد الغروية المحبة للماء المستخلصة من مسحوق نوى البلح مكونه طبقة رقيقة واقية للحد من امتصاص الزيت أثناء عملية القلى العميق. تم إجراء التحاليل الكيميائية لمحلول مسحوق نوى البلح وأوضحت النتائج أن هذا المحلول يحتوى على مواد غروية تتراوح كميتها مابين٨,٢ -١٧,٩ جم/كجم وهي كافية لتكوين تلك الطبقة الرقيقة على البطاطس وكذلك وجد أن المحلول يحتوى على مواد فينولية مضادة للأكسدة تتراوح ما بين٠,٣١-١,٩٥ جم/كجم مما يزيد من القيمة التغذوية للمحلول. درس تأثير التراكيزات المختلفة لمحلول مسحوق نوى البلح فى مدى يتراوح ما بين (٠,٥- ٦ ٪) على كمية الزيت وكمية الماء فى البطاطس قبل إجراء عملية القلى العميق وبعدها. وأوضحت النتائج أن غمر البطاطس فى محلول تركيزه ٤٪ لمدة خمس دقائق أدى إلى إنخفاض ملحوظ فى كمية الزيت الممتص بنسبة ٧٧,٧٪ بعد عملية القلى العميق بزيت النخيل. وتعتبر هذه النسبة أعلى من النسب المنشورة فى الدراسات السابقة حتى الآن وهذا يعكس مدى فاعلية الطبقة المتكونة والمقترحة بالبحث الحالى مقارنة بما سبق. وكذلك أثبتت النتائج أن عملية تجفيف البطاطس قبل القلى لم تحسن من هذه النسبة مما يجعل الطريقة المقترحة بسيطة وسهلة التطبيق. وأظهرت تحاليل القوام واللون أيضا أن البطاطس المقلية تتميز بخواص أفضل من حيث القرمشة واللون الذهبى مقارنة بمثيلاتها من البطاطس المعدة باستخدام طبقة الميثيل سليلوز المعروفة. وأكد تقييم الخواص الحسية القبول العام للبطاطس المقلية. ومن هنا أوضحت الدراسة الحالية لأول مرة فاعلية محلول المواد الغروية المحبة للماء المستخلصة من مسحوق نوى البلح لإعداد بطاطس صحية من حيث انخفاض نسبة الزيت الممتص بها وذات قبول عام من حيث الطعم واللون والمظهر وغيره. ولذلك تعتبر الطريقة المقترحة بالبحث الحالى طريقة بسيطة وسريعة وسهلة التطبيق داخل المنزل للحد من كمية الزيت الممتص بالبطاطس واسعة الاستخدام ليس فقط فى مجتمعنا بل أيضا فى العالم بأسره.