Egyptian Journal of Food Science
http://ejfs.journals.ekb.eg/

Evaluating the Technological and Biological Effects of Some Fried Vegetables and Fruits Chips Treated With Chitosan–Pectin Nanoparticles

Marwa A. Sheir[1*], Rania A. Ahmed[2], Khaled.Y. Farroh[3]
[1]Food Technology Research Institute, Agriculture Research Center, Giza, Egypt.
[2]Department of Zoology, Faculty of Science, Suez University, Suez, Egypt.
[3]Nanotechnology and Advanced Materials Center Lab .Agriculture Research Center. Giza.Egypt

NANOTECHNOLOGY is a novel field transforming traditional food sector into a dynamic and innovative food industry. The objective of this work was to evaluate the utilization efficiency of chitosan–pectin nanoparticles (CS/Pec NPs) in improving the production quality of some fried slices of vegetables and fruits (banana, potato and cassava) and the impact on the fried products' quality attributes (PQA) effects of (CS/Pec NPs) on Albino rats were monitored along 3 months via biochemical assays, liver histology and histochemical demonstration of glycogen. The obtained results showed that immersing in CS/Pec NPs solution as pre-frying treatment (for 1 min) showed to be an effective way to decrease acrylamide formation, oil uptake and malonaldehyde level in fried slices products to (46.95%, 35.32% & 1.22 mg/kg) for fried banana, (54.59%, 29.76% & 2.14 mg/kg) for fried potato and (49.62%, 4.95% & 1.98 mg/kg) for fried cassava and improved the sensory and texture properties. Moreover, no recorded animal deaths throughout the 3 months of experiment. Rats fed with CS/Pec NPs treated fried banana, fried potato and fried cassava with revealed enhancements in hepatic tissue, restoration of glycogen in hepatocytes and significant improvements in biochemical parameters when compared with rats control group. Therefore, this paper may help food manufacturers to produce healthier fried food and to keep a better technological quality.

Keywords: Nanotechnology, Chitosan–Pectin nanoparticles, Fried chips, Liver histology, Liver glycogen.

Introduction

Fried potato, cassava and banana chips are popular snack products. In most countries around the world, the ever-increasing consumption of snack products has made them a considerable component of a human diet and their popularity owes to a certain kind of "fashion" to be eaten with friends, especially among children and adolescents (Tajner-Czopek et al., 2021). Deep-fat frying (or less commonly deep frying), it is a classical cooking technique of antiquity and it was preferred chiefly because of its conferment of a crisp texture, swiftness, amenity, distinctive qualities, consumer acceptability and extend the shelf life of agricultural products. This process causes some of healthy and physicochemical changes such as color changes, crust formation, starch gelatinization, oil uptake, water loss and lead to increased incidence of cancer, diabetes, hypertension or coronary heart disease.

Consumers are increasingly demanding healthier alternatives to fried foods, especially with reduced fat content, so, a pre-treatment step before frying may be the best point of interest in the manufacture of low-fat products. Pre-treatments are mainly used in any conventional fruit and vegetable product to reduce energy coast, oil uptake , moisture content and to prolong

*Corresponding author: E-mail: Marwa.sheir@yahoo.com
Received: 17/12/2021; accepted: 29/1/2022
DOI: 10.21608/ejfs.2022.111665.1117

the shelf life owing to the improving of quality (Udomkun & Innawong, 2018; Omara et al., 2019) Nanotechnology was used in food products to enhance safety, quality, shelf life, nutritional value, decrease the cost and used in the manufacture of healthier food containing low sugar , low fat, and low salt (Nile et al., 2020). The application of nanotechnology in food manufacture can be divided into two main groups; food nanosensing and food nanostructured ingredients (Singh et al., 2017). Nanostructured food ingredients cover a large area including food manufacturing such as; food additives, anticaking agents, gelating agents and nanocapsules and nanocarriers, nanostructured smart packaging, active packaging and bio-based packaging are considered. Whereas the field of food nanosensing provides improved food quality and safety (Primožič et al., 2021).

The objective of this research was to evaluate the changes in product quality attributes (PQA) such as consumer acceptability, hardness, acrylamide levels, oil reduction, and malonaldehyde content for fried fruits and vegetables (banana, potato and cassava) when applying pre-frying treatments with chitosan–pectin nanoparticles solution. In addition, to evaluate the effects of our investigated products on albino rats.

Materials and Methods

Materials

Chemicals

Chitosan (CS) (molecular weight 50,000-190,000 Da, degree of deacetylation 75-85percent, acetic acid, sodium hydroxide, sodium tripolyphosphate (TPP) and pectin (esterification degree, EE 65percent) were purchased from Sigma-Aldrich,USA. All the chemicals used in this investigation were analytical grade.

Sample

Commercial samples of cassava roots obtained from the Field Crops Research Institute, ARC, Ministry of Agriculture and Land Reclamation, Egypt .Potato tuber var. *spunta* obtained from the Horticultural Research Institute, ARC, Ministry of Agriculture and Land Reclamation, Egypt .In addition, Fresh bananas (var. *Williams*) were purchased from a local market in El- Menoufia Governorate, Egypt. Palm oil was supplied by Malaysian Palm Oil Board (MPOB).

Methods

Preparation of Chitosan–pectin nanoparticles

Chitosan–pectin nanoparticles (CS/Pec NPs) were prepared according to (Rampino et al., 2016) with some modifications. Briefly, chitosan (CS) aqueous solution (0.05% w/v) was prepared by dissolving CS in acetic acid solution (1% v/v) at room temperature and adjusted PH to 5 with sodium hydroxide. Pectin solution was prepared in deionized water (0.05% w/v). The obtained pectin solution was added drop wise to chitosan solution. Subsequently, TPP solution (0.02% w/v) was added drop wise to CS/pectin solution under vigorous stirring for 30 min. Pec/CS NPs were prepared from a mixture of chitosan solution and pectin by homogenizing at 18000 rpm for 30 min. The resulting Pec/CS NPs were centrifuged at 20000g for 30 min. The pellet suspended in deionized water then freeze-dried before further use or analysis. The size (Z-average mean) and zeta potential of the nanocomposites were analyzed by photon correlation spectroscopy and laser doppler anemometry, respectively, in triplicate using a Zetasizer 3000HS (Malvern Instruments, UK). The morphology of CS/Pec NPs was imaged by High Resolution Transmission Electron Microscope (HR-TEM) operating at an accelerating voltage of 200 kV (Tecnai G2, FEI, Netherlands). Diluted CS/Pec NPs solution was ultra-sonicated for 5 min to reduce the particles aggregation. Using micropipette, three drops from the sonicated solution were deposited on carbon coated-copper grid and left to dry at room temperature.HR-TEM images of the CS/Pec NPs that deposited on the grid were captures for morphological evaluation. The chemical structure of as prepared CS/Pec NPs was assessed using X- ray Diffraction (XRD) technique. The corresponding XRD pattern was recorded in the scanning mode (X 'pert PRO, PAN analytical, Netherlands) operated by Cu K radiation tube (= 1.54 Å) at 40 kV and 30 mA. The obtained diffraction pattern was interpreted by the standard ICCD library installed in PDF4 software. All the preparation and characterization processes were conducted at Nanotechnology and Advanced Materials Central Lab (NAMCL), Agricultural Research Center, Egypt.

Preparation of vegetables and fruits fried slices

The banana, potato and cassava were peeled manually, washed with tap water, and then sliced to a thickness of 1.5-2 mm. Each type was divide into control and pretreated treatments; 1) B1, banana control without treatment. 2) B2, pre-

treated banana with Chitosan–Pectin solution immersing for 1 min. 3) P1, control potato without pre-treatment applied. 4) P2, pre-treated potato with Chitosan–Pectin solution immersing for 1 min. 5) C1, as control cassava, without pre-treatment applied. 6) C2, pre-treated cassava with Chitosan–Pectin solution immersing for 1 min. The frying process was carried out in domestic fryer model (Arion at 180 ºC for 4 min) with a capacity of 5 L of palm oil. After frying, slices samples were drained and allowed to cool.

Quality assessment of fried chips

Acceptability test

Ten experienced judges from the Food Technol. Res. Institute, Agric. Res. Center, and Giza, Egypt were chosen to evaluate the acceptability of the fried slices products according to Watts et al., (1989).

Texture profile

Hardness of fried products were measured using TA.XT Texture Analyzer (Stable Micro System, Surrey, UK) as described by Pedreschi & Moyano (2005).

Chemical composition

The moisture content of fried samples and oil uptake (OU) were determined according to (AOAC, 2000). Oil uptake reduction % (OUR) in the treated samples compared to the untreated one was calculated as follows: OUR =1 – (OU treated/OU untreated) x 100 (Suarez et al., 2008). Malonaldehyde level was determined according to Pearson (1970) and Woyewoda et al. (1986) Acrylamide was determined according to the method described by Gokmen & Senyuva (2006).

Biological experimental design

Male Sprague Dawley albino rats (64 rats) weighing (180±5g) were kept in individual stainless steel cages under hygienic conditions and fed one week on basal diet according to (Reeves,1993) for adaptation in the animal house of Research Institute of Ophthalmology, Giza, Egypt. Rats. The basal diet was prepared according to the formula mentioned by (Lane–Peter & Pearson, 1971).

The supplemented diets were prepared by adding 10% of each on the commonly used fried slices powder to the basal diet. After one week period (for acclimatization),the experimental animals were divided into 8 groups (8 rats for each)): Group (1): Fed basic diet as negative control group(G1) Group(2): fed basic diet and Chitosan–Pectin nanoparticles (CS/Pec NPs) orally at a dose of (200 mg /kg bw/day) according to Abouzaid et al. (2019) Group(3): Fed basic diet supplemented with 10% of untreated fried banana (G3). Group (4): rats were fed on basal diet supplemented with 10% treated fried banana (G4). Group (5): Fed basic diet supplemented with 10% of untreated fried potato (G5). Group (6): Fed basic diet supplemented with 10% of treated fried potato (G6).Group (7): Fed basic diet supplemented with 10% of untreated fried cassava (G5). Group (8) Fed basic diet supplemented with 10% of treated fried cassava (G6).

At the end of the experimental period (90 days) body weight gain percent (BWG %) was calculated according to the method the method of (Chapman et al., 1959). Rats were fasted over night before sacrificing, blood was collected then centrifuged. Serum was separated and stored at -20 °C for biochemical assay of serum (AST & ALT) Reitman & Frank (1957), Serum level of malondialdehyde (MDA) was assayed according to Uchiyama and Mihara (1978).

Total Antioxidant capacity (TAC) (Woodford & Whitehead 1998), tumor necrosis factor alpha (TNF-α) was determined according to the manufacturer's instructions using commercial kits obtained from (eBioscience Vienna, Austria). Lactate dehydrogenase (LDH) was determined according to the method of Horcker & Kornberg (1948).All of the rats' livers were removed, and then fixed in 10% neutral formalin, dehydrated, cleared and embedded in paraffin wax. Paraffin sections of 5 microns thickness were prepared and stained with routine haematoxylin and eosin stain (Drury & Wallington, 1980). For histochemical demonstration of glycogen; paraffin sections were stained with Periodic acid Schiff's (PAS) stain (Hotchkissr, 1948).

Statistical analysis

The obtained data were subjected to one-way ANOVA using SPSS, ver. 22 (IBM Corp. Released 2013). Data were treated as a complete randomization design according to (steel et al., 1997).

Results and Discussion

Nanoparticles quality evaluation

Dynamic Light Scattering (DLS) analysis of (CS/Pec NPs)

DLS was used to determine hydrodynamic diameter in the nanometer range. The size of CS/Pec NPs was 154.4 nm and zeta potential 29.8 mV Fig. 1.

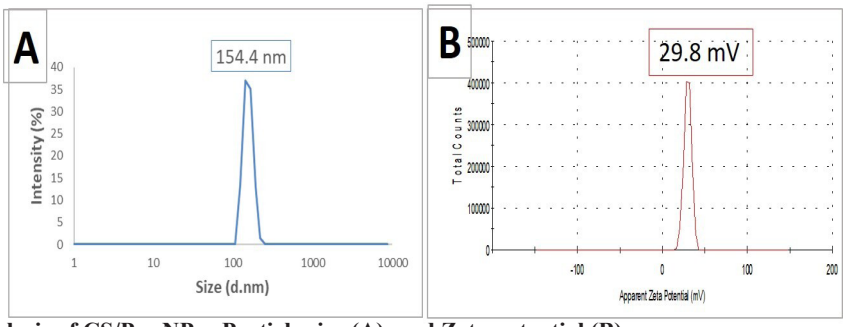

Fig. 1. DLS analysis of CS/Pec NPs. Particle size (A), and Zeta potential (B).

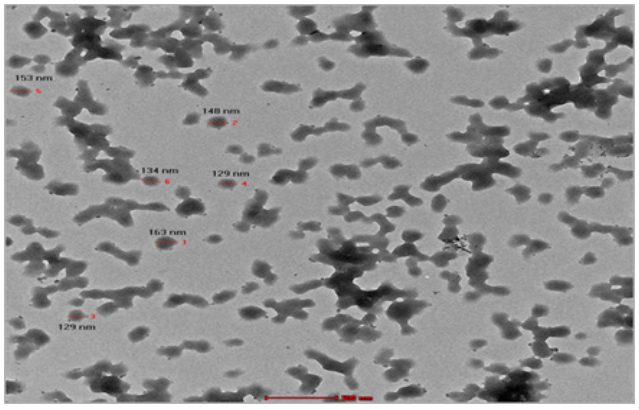

Fig. 2. TEM image of CS/Pec NPs.

High Resolution Transmission electron microscope (HR-TEM) result of (CS/Pec NPs)

HR-TEM gave us information on the particle shape and the determination of particle size. Typical HR-TEM micrograph of the CS/Pec NPs was shown in Fig. 2.The CS/Pec NPs have nearly spherical shape, smooth surface and size range of about 143 nm.

X-Ray diffraction (XRD) pattern of (CS/Pec NPs)

X-Ray diffraction patterns of CS/Pec NPs is shown in Fig. 3. The XRD pattern of CS/Pec NPs showed a broad typical hump peak start from 2θ = 10° to 2θ = 30°. The main peak of CS/Pec NPs pattern was observed at 2θ = 20°

Technological results

Organoleptic and texture analyses of Fried Chips

Results in Table 1 and Fig 4 illustrated that immersing of banana, potato and cassava chips in (CS/Pec NPs) solution before frying could improve odor, color, crisps, taste of fried chips and oil uptake. The Maillard reaction is may be responsible for the tasty flavor and brown color of products of fried food**.** Obtained results agreed with Suyatma et al. (2015) who investigated that, pre-treatment with pectin coating could prevent excessive leaching of amino acids and sugar, known as the Maillard reaction, while also protecting the cellular structure of the banana tissue from damage during deep-fat frying, resulting in higher preference scores for banana chips in all attributes. As shown in Table 1, immersion in (CS/Pec NPs) solution resulted a significant decrease in hardness profile. The crispiness of the final fried crust is an important index in fried food. Some of the texture changes happened when moisture was removed from the crust during frying. The hardness or breaking force (N) is an indicator of the extent of crispness. A high hardness value corresponds with a lower crispness (Ramli & Rosdi, 2019).

Analytic results

During frying; the water content of food reduces, while the oil replaces water (Al-Asmar et al. 2018)**.** As shown in Table 2, the obtained results indicated that, fried banana , potato and cassava chips that fried directly without any pre-frying treatment (control) absorbed (34.37, 43.68 and 27.40%) oil respectively, while pre-frying

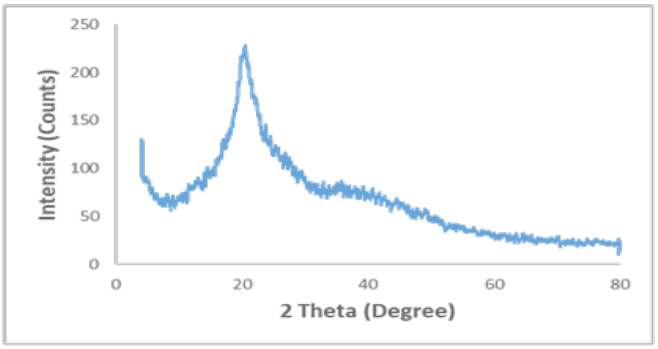

Fig. 3. X-ray powder diffraction patterns of CS/Pec NPs.

TABLE 1. Sensory evaluation and hardness profile of fried banana, potato and cassava chips at 180°Cfor 4 min

Treatments	Sensory evaluation Parameters					Hardness (N)
	Odor	Color	crisps	Taste	Oil Uptake	
B1	8.14±0.10^{b}	7.92±0.17^{bcd}	7.67±0.08^{c}	8.38±0.06^{b}	7.97±0.14^{b}	9.5±0.26^{a}
B2	8.84±0.13^{a}	9.14±0.04^{a}	9.17±0.16^{a}	9.41±0.09^{a}	8.74±0.18^{a}	7.77±0.29^{b}
P1	7.54±0.09^{c}	7.42±0.12^{d}	8.07±0.18^{bc}	7.95±0.17^{c}	7.04±0.17^{c}	5.65±0.14^{c}
P2	8.54±0.29^{ab}	8.02±0.19^{bc}	8.47±0.13^{b}	9.11±0.12^{a}	7.94±0.18^{b}	4.52±0.10^{d}
C1	7.54±0.27^{c}	7.52±0.12^{cd}	8.37±0.24^{b}	7.87±0.18^{c}	7.43±0.21^{c}	3.52±0.17^{e}
C2	8.74±0.21^{a}	8.42±0.33^{b}	8.47±0.36^{b}	9.08±0.21^{a}	8.34±0.20^{b}	2.81±0.13^{f}
LSD at 0.05	0.56	0.52	0.60	0.42	0.51	0.60

Different letters indicate the significant differences (P>0.05) between any two means, within the same column. B1=untreated fried banana B2= Pretreated fried banana P1=untreated fried potato P2= Pretreated fried potato C1=untreated fried cassava C2= Pretreated fried cassava.

immersing significantly decreased oil uptake to reach 22.23% for banana chips, 30.68 for potato chips and 17.05% for cassava chips. Oil uptake reduction reached to 35.32, 29.76 and 37.77% respectively. On contrary, moisture content of the same samples increased to 20.50, 26.94and 4.95% respectively compared with the same control samples which were (13.03, 17.61 and 3.13%). This result agreed with the fact that increasing moisture content of fried samples associated with decreasing in oil content (Ali et al., 2012). Al-Asmar et al. (2018) reported that pectin caused a decrease in oil uptake .aldehydes and ketones.

On the other hand, immersing process prior to frying was found to be an effective pretreatment for lowering acrylamide levels. So that, Immersing process in (CS/Pec NPs) solution reduced acrylamide content in banana chips from 2000.70 to 1061.33 µg/Kg; in potato chips from 3001.33 to1362.67 µg/Kg and in cassava chips from 2561.67 to1290.00 µg/Kg, respectively, and was effective in reducing acrylamide up to 46.95% for banana chips, 54.59 % for potato chips and 49.62% for cassava chips. These findings were in line with those reported by Zeng et al. (2010) who explained that pectin coating could reduce heat penetration from the oil to the banana slices during the frying process and could interact with sugar, which is an acrylamide precursor, resulting in less acrylamide formation in banana slices and Suyatma et al. (2015) which found that the synergistic effect of blanching and pectin coating caused a great acrylamide reduction up to 91.9%

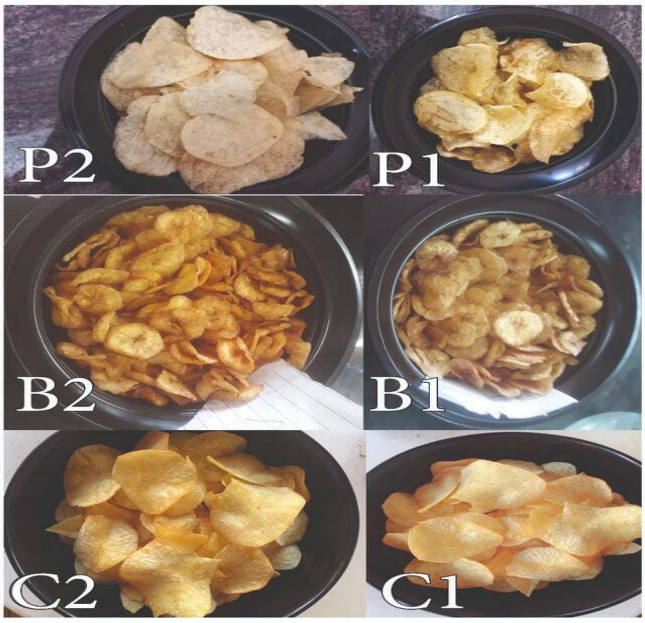

Fig. 4. Photos of fried vegetables and fruits slices. B1=untreated fried banana B2=Pretreated fried banana P1=untreated fried potato P2= Pretreated fried potato C1=untreated fried cassava C2= Pretreated fried cassava.

and 90.8%, for samples pre-treated with edible coating after blanching at 90 and 100 degrees Celsius, respectively. Also Champrasert et al. (2021) found that, coating potatoes with alginate, pectin and chitosan (1% w/v) prior to frying dramatically inhibited acrylamide formation by 54%, 51% and 41% respectively.

The malondialdehyde (MDA) contents of all studied samples as an indication of fat oxidation in fried chips were presented in Table 2. It was observed that the pre-frying treatment with (CS/Pec NPs) caused significantly ($P < 0.05$) decrease in MDA values compared with that fried directly without any pre-frying treatment (control). This is probably due to the high content of oil uptake in control samples. This might be oxidised by oxygen, resulting in the formation of reactive oxygen species. Moreover, Mousa (2021) reported that, lowering fat content reduced MDA production significantly.

Biological results

Anatomical observations

The present work investigated that, there were no deaths in any of the animal groupings. During the 90-days period, none of the groups displayed abnormal behaviours or general abnormal symptoms when compared to the untreated controls. BWG% significantly increase in untreated fried chips products (G3, G5 & G7) compared with control group and other treated groups .This may be due to its high contents of fats as shown in Table (2). There were insignificant change in control group (G1) and treated group with (CS/Pec NPs) solution (G2) and between (G3, G6 &G7) and between (G4 & G8).

Biochemical parameters

Data obtained from the biochemical examinations 90 days following the application of the (CS/Pec NPs) solution are shown in Tables 3. There were in-significant differences in the AST, ALT& MDA values of the (CS/Pec NPs) treated and control animals (G 2 and G 1). Additionally orally treatment with (CS/Pec NPs) solution (G2) caused a significant increase in TAC value and significant decrease in TNF-α & LDH compared with control group. However, by comparing with control rats, and with rats fed on fried chips immersing in (CS/Pec NPs) solution before frying (G4,G6 and G8), the parameters of AST, ALT, MDATNF-α and LDH significantly increase ,while TAC value gave the oppose result in rats fed on untreated fried chips groups(G3,G5 and G7). No significant difference in MDA, TNF-α, LDH and TAC between (G1&G4), also there was in significant change in AST between (G1, G2&G4). These results may be due to the higher contents of acryl amide in untreated fried chips (G1, G2-& G3) as shown in Table 2.

TABLE 2 . Quality evaluation (moisture, fat, acrylamide and Malonaldehyde content) of fried banana, potato and cassava chips at 180 °C for 4 min

Treatments	Parameters					
	Oil uptake (%)	Moisture (%)	Oil uptake reduction (%)	Acrylamide µg/Kg	Acrylamide reduction (%)	Malonaldehyde content (MDA, mg.kg^{-1})
B1	34.37±0.72^{b}	13.03±0.73^{d}	-	2000.70±2.63^{c}	-	1.82±0.04^{d}
B2	22.23±0.99^{e}	20.50±0.15^{b}	35.32±2.4	1061.33±1.86^{e}	46.95±0.19	1.22±0.03^{c}
P1	43.68±1.58^{a}	17.61±0.5^{c}	-	3001.33±27.45^{a}	-	3.40±0.30^{a}
P2	30.68±0.93^{c}	26.94±0.93^{a}	29.76±3.71	1362.67±66.12^{d}	54.59±2.32	2.14±0.02^{c}
C1	27.40±0.52^{d}	3.13±0.19^{f}	-	2561.67±56.46^{b}	-	2.86±0.05^{b}
C2	17.05±0.53^{f}	4.95±0.32^{e}	37.77±1.15	1290.00±34.64^{d}	49.62±2.56	1.98±0.02^{c}
LSD at 0.05	2.93	1.69	-	122.77	-	0.38

Different letters indicate the significant differences (P>0.05) between any two means, within the same column.

B1=untreated fried banana B2= Pretreated fried banana P1=untreated fried potato P2= Pretreated fried potato C1=untreated fried cassava C2= Pretreated fried cassava.

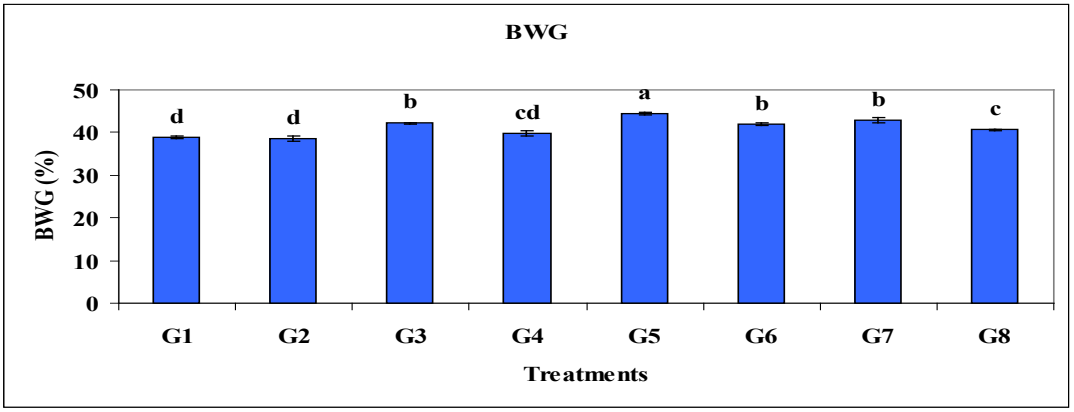

Fig. 5. Body weight gain % for control group compared with other groups

Hendawy & Hendawy (2019) indicated that, acrylamide administration decreased serum Glutathione (GSH) and increased (AST,ALT and MDA) levels when compared to the control group .Additionally Donmez et al. (2020) reported that, acrylamide caused an increased in ALT,AST,MDA and TAC. To the extent of our knowledge, there were not any studies on the biochemical examinations of chitosan-pectin nanoparticles, however, some studies discussed the antioxidants effect of chitosan nanoparticles Abouzaid et al. (2019) revealed that, Oral administration of chitosan nanoparticles ameliorates liver injuries induced by DEN by decreasing the values of biochemical parameters as ALT, AST ,GGT, Alkaline Phosphatase, Urea and L-MDA and increasing the activities of antioxidant parameters as CAT, GSH and SOD**.** Gebreel et al. (2021) revealed that chitosan NPs modulated the effects of EAC on kidney and liver functions and structures, which is indicated by normalization of serum (ALT, AST, ALP, Total protein, Albumin, Urea, Creatinine, lipid profile, Na, K, Cl, Ca) levels.

Histopathological assessment

Figure 6 (a) shows histopathological alterations observed in livers of rats among all experimental groups. Microscopic examination of sections control rats livers showed the classical hepatic lobules with central vein surrounding with radiating hepatic cords formed of normal

TABLE 3. Changes in some serum biochemical enzymes levels in experimental groups

Treatments	Parameters					
	AST (U/L)	ALT (U/L)	TAC (mmol)	MDA (µmol)	TNF-α (Pg/ml)	LDH (µL)
G1	75.20±0.55^{f}	37.99±0.26^{g}	3.29±0.30^{b}	1.65±0.04^{fg}	112.39±0.55^{f}	129.23±0.62^{e}
G2	72.63±0.44^{f}	36.17±0.20^{g}	4.11±0.28^{a}	1.19±0.04^{g}	105.97±2.80^{g}	123.87±0.58^{f}
G3	141.90±0.85^{c}	91.83±0.88^{c}	1.72±0.06^{de}	4.63±0.26^{c}	128.17±0.44^{c}	140.20±0.55^{c}
G4	71.57±0.45^{f}	66.00±1.15^{f}	3.38±0.23^{b}	2.00±0.03^{f}	115.27±0.54^{f}	129.03±0.84^{e}
G5	169.43±2.81^{a}	118.17±0.93^{a}	1.06±0.12^{f}	7.77±0.15^{a}	139.10±0.49^{a}	155.20±1.74^{a}
G6	103.20±1.14^{d}	86.67±0.81^{d}	2.17±0.18^{d}	3.70±0.42^{d}	122.57±2.08^{d}	136.87±0.70^{d}
G7	156.10±1.46^{b}	107.50±1.14^{b}	1.33±0.12^{ef}	5.69±0.23^{b}	133.43±0.98^{b}	148.27±0.43^{b}
G8	89.73±1.82^{e}	74.10±1.19^{e}	2.84±0.20c	2.81±0.36^{e}	119.67±0.41^{e}	130.50±0.40^{e}
LSDT at 0.05	4.25	2.69	0.60	0.71	4.01	2.51

Different letters indicate the significant differences (P>0.05) between any two means, within the same column.

polygonal hepatocytes with intact cell membrane and central rounded nucleus, in addition to free sinusoids with Kupffer cells (Fig 6a). Treating rats treated with chitosan–pectin nanoparticles didn't induce any histopathological changes as the hepatic tissues were well formed (Fig 6 b).

Hepatic sections obtained from rats treated with each of fried banana, fried potato, and fried cassava showed marked histopathological changes when compared with those obtained from control group. Hepatic histoarchitecture was deformed with abnormal arrangement of hepatocytes, activated Kupffer cells and abnormal sinusoids appeared. Periportal aggregation of inflammatory cells, sever hemorrhage, widened and/or congested blood vessels were noted. However, additional pathological patterns were recorded in fried potato treated group such as bile duct proliferation and necrosis (Fig 6c, 6d, 6e).

Results are in agreements with many authors who reported the histopathological effects of acrylamide on hepatic tissues. Acrylamide caused loss of hepatic architecture with degenerated hepatocytes with deeply stained pyknotic shrunken nuclei, dilation and congested of the central vein. The nuclei exhibited marked nuclear degeneration and pyknotic nuclei. The hepatocytes are separated by wide congested sinusoids lined by darkly stained pyknotic Von Kupffer cells with extravasation of red blood cells. The portal area showed dilated portal vein, bile duct and hepatic artery and marked polymorph cellular infiltration was noticed. The portal areas revealed massive peri-portal cellular infiltration, dilated congested portal vein and hepatic artery branches and proliferation of bile duct (Hendawy & Hendawy, 2019; Ali et al., 2020; Donmez et al., 2020; Salman et al., 2020). Rats fed treated fried banana, fried potato, and fried cassava with chitosan–pectin revealed advanced degree of improvement of hepatic tissue when compared with untreated fried banana, fried potato, and fried cassava. The hepatic lobules appeared well formed; all the inflammatory features grades were reduced markedly (Fig 6f, 6g, and 6h). However, rats fed on treated fried potatoes chips still revealed limited pathological changes as dilated vessels (Fig 6f).

Histochemical demonstration of General Carbohydrates

Sections stained by periodic acid Schiff (PAS) demonstrated the glycogen and revealed PAS-positive glycogen granules in the cytoplasm of hepatocytes (magenta color), reflecting normal rich glycogen content of the hepatocytes in the cytoplasm of the hepatocytes in both control group and rats treated with Chitosan–Pectin nanoparticles group (Fig 7a & 7b). Rats fed on fried banana, fried potato, and fried cassava showed marked glycogen depletion, thus a weak positive reaction hepatocytes cytoplasm by comparing with control group reflecting a reduction in the glycogen content of the hepatocytes (Fig 7c, 7d & 7e). The reducing effects of acrylamide on glycogen contents in hepatic tissues has been previously reported as acrylamide caused weak PAS reaction in some hepatocytes, and absence of the reaction from other cells (Donmez et al., 2020; Salman et al., 2020). Rats fed on treated fried potato, fried banana and fried cassava with Chitosan–Pectin nanoparticles revealed advanced restoration of glycogen in hepatocytes when compared with fried banana, fried potato, and fried cassava treated rats (Fig. 7g, 7f,

7h). To the best of our knowledge, there were not any studies on the hepatoprotective role of chitosan-pectin nanoparticles; liver however, few studies discussed the histoprotective effects of chitosan nanoparticles on. El-Denshary et al. (2015) reported that chitosan nanoparticles reduced significantly the CCl4- induced hepatocytes degenerative changes as, steatosis and inflammation. As was demonstrated by Oksal et al. (2020) nanoparticles of chitosan-P tectorius fruit extract decreased the lipid droplets depositions in hepatocytes of hypercholesterolemic rats via suppressing biosynthesis of cholesterol. Chitosan nanoparticles played a synergistic effect against d-galactose induced-aging hepatotoxicity in male rats as it was exhibited a marked restoration of almost normal histological structures of hepatic tissues. However, small congested central vein still observed (Al-Elisa, 2018).

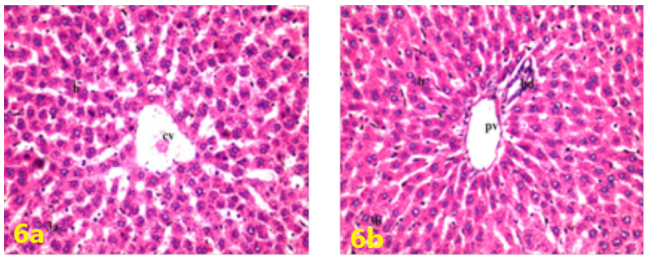

Fig (6a). Photomicrograph of liver section taken from a control rat showing normal architecture with normal appearance of hepatocytes (h), sinusoid (s) and vascular

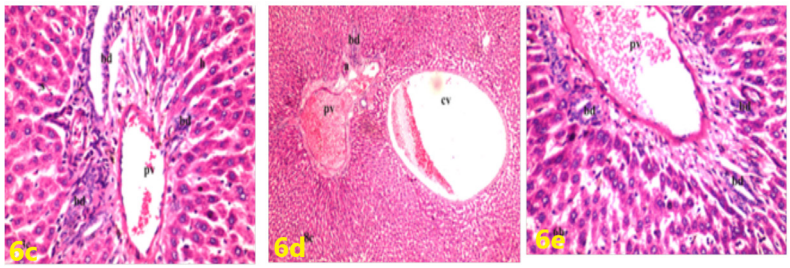

Fig (6c). Photomicrograph of liver section taken from fried potato treated animals showing most portal area showed severe dilated congested portal vein (pv), and proliferated bile duct (bd). (H & E. 400X).Fig (6d): Photomicrograph of liver section taken from fried banana showing scattered congested dilated central vein (pv) and portal vein (pv) portal and proliferated bile duct (bd) (H & E. 100X). Fig (6e): Photomicrograph of liver section taken from cassava treated animals showing most portal area showed severe dilated congested portal vein (pv), and proliferated bile duct (bd). (H & E. 400X).

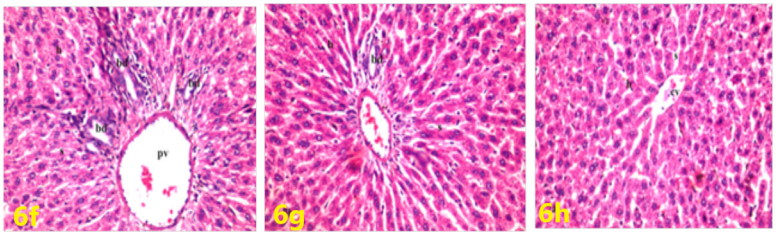

Fig (6f). Photomicrograph of liver section taken from fried potato + nanoparticles treated animals showing few portal area showed moderate dilated congested portal vein (pv), and proliferated bile duct (bd). (H&E. 400X). Fig (6g):Photomicrograph of liver section taken from fried banana + nanoparticles showing normal architecture with normal appearance of hepatocytes (h), sinusoid (s) and vascular channels as central vein (cv). (H & E. 400X). Fig. (6h): Photomicrograph of liver section taken from fried cassava + nanoparticles showing normal architecture of portal area with normal appearance of portal vein (pv), bile duct (bd) (H & E. 400X).

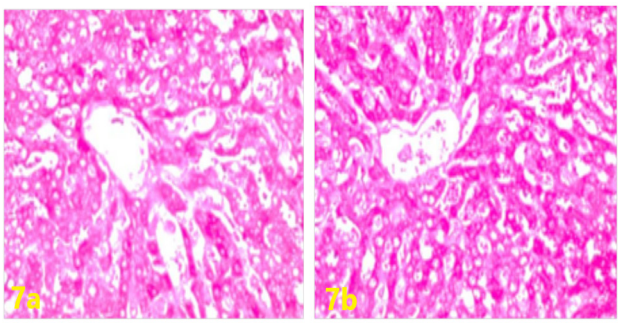

Fig (7a). Photomicrograph of liver section taken from a control rat showing normal appearance of hepatocytes with strong expression of glycogen (PAS, 400X).

Fig (7b). Photomicrograph of liver section taken from chitosan-pectin nanoparticles showing normal appearance glycogen deposition in hepatocytes. (H & E. 400X).

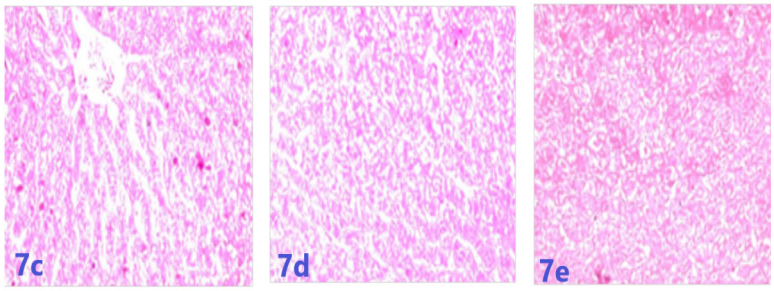

Fig (7c). Photomicrograph of liver section taken from fried potato treated animals showing severe reduction of glycogen in hepatic tissues with absence of glycogen in most of hepatocytes (PAS. 400X).

Fig (7d). Photomicrograph of liver section taken from fried banana showing weak expression of glycogen in hepatocytes (PAS. 400X).

Fig (7e). Photomicrograph of liver section taken from cassava treated animals showing significant reduction of glycogen in liver. (PAS. 400X).

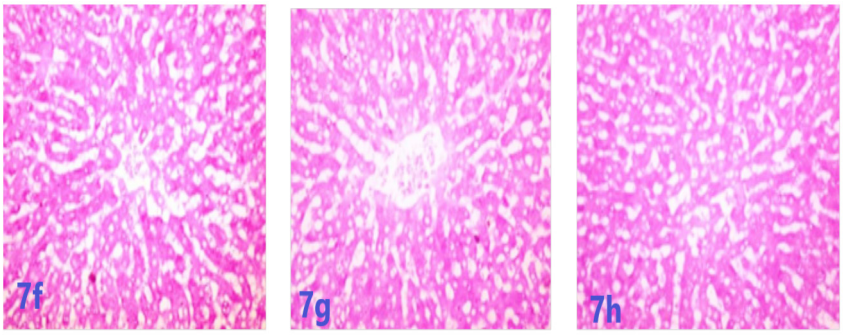

Fig (7f). Photomicrograph of liver section taken from fried potato + nanoparticles treated animals showing marked restoration of glycogen in most of hepatocytes (PAS. 400X).

Fig (7g). Photomicrograph of liver section taken strong staining of glycogen (PAS. 400X). from fried banana + nanoparticles showing normal architecture with normal appearance of hepatocytes with normal glycogen distribution (PAS 400X).

Fig (7h). Photomicrograph of liver section taken from fried cassava + nanoparticles showing normal architecture hepatocytes which reveals

Conclusions

In conclusion, chitosan–pectin nanoparticles (CS/Pec NPs) solution showed to be helpful in the production of healthier and safe fried slices, by the reduction of acrylamide formation, oil uptake and malonaldehyde content. This could encourage authors to recommend application of chitosan–pectin nanoparticles (CS/Pec NPs) solution in the future for producers due to its safety, tasteless, colourless, low cost properties, in addition to enhanced technological quality.

References

AOAC (2000) Association of Official Analytical Chemists. In Official Methods of Analyses, **17**th ed. Gaithersburg.M.D.

Abouzaid, O., Elsonbaty, S., Moawad, F. and Abdelghaffar, M. (2019) Antioxidants and hepatoprotective effects of chitosan nanoparticles against hepatotoxicity induced in rats. *Benha Veterinary Medical Journal*, **36**(1), 252-261. https://doi.org/10.21608/bvmj.2019.111628.

Al-Asmar, A., NaviglioD., Giosafatto, C. and Mariniello, L. (2018) Hydrocolloid-based coatings are effective at reducing acrylamide and oil content of French fries. *Coatings*, **8**(4), 147**.** https://doi.org/10.3390/coatings8040147.

Ali, A., Ibrahim, A., Ahmed, A. and Talaat, E. (2020) Histological study of toxic effects of acrylamide on the liver and kidney of adult male albino rats. *Malaysian Journal of Medical Research*, **31**(3), 345-350.

Ali, H.S., Abdel-Razek, A.G. and Kamil, M.M. (2012) Effect of pre-frying treatments of french fried potatoes to achieve better oil uptake reduction for health and technological aspects. *Journal of Applied Sciences Research*, **8**(10), 5018-5024.

Champrasert, O., Chu, J., Meng, Q., Viney, S., Holmes, M., Suwannaporn, P. and Orfila, C. (2021) Inhibitory effect of polysaccharides on acrylamide formation in chemical and food model systems. *Food Chemistry*, **363.** 130213. ISSN 0308-8146. https://doi.org/10.1016/j.foodchem.2021.130213.

Chapman, D., Castilla, R. and Cambell, J. (1959) Evaluation of protein in foods: a method for the determination of protein efficiency ratio. *Canadian journal of biochemistry and physiology***, 37**, 697-686. https://doi.org/10.1139/y59-074

Donmez, D. B., Kacar, S., Bagci, R., and Sahinturk, V. (2020) Protective effect of carnosic acid on acrylamide-induced liver toxicity in rats: Mechanistic approach over Nrf2-Keap1 pathway. *Journal of biochemical and molecular toxicology*, e22524. *Advance online publication*. https://doi.org/10.1002/jbt.22524

Drury, R.A and Wallington, E.A. (1980) Carleton's Histological Techniques, 5th ed. Oxford: *Oxford University Press*, p. 362.

Al-Eisa, R.A. (2018) Synergistic antioxidant capacity of chitosan nanoparticles and lycopene against aging hepatotoxicity induced by d-galactose in male rats. *International Journal of Pharmacology*, **14**, 811-825. https://doi.org/10.3923/ijp.2018.811.825.

El-Denshary, E., Aljawish, A., El-Nekeety, A., Hassan, N., Saleh, R., Rihn, B. and Abdel-Wahhab, M. (2015) Possible synergistic effect and antioxidant properties of chitosan nanoparticles and quercetin against carbon tetrachloride-induce hepatotoxicity in rats. *Soft Nanoscience Letters*, **5**, 36-51. https://doi: 10.4236/snl.2015.52005.

Gebreel, D. T., Elatrash, A. M., Atta, F. A., Tousson, E., and Allam, S. (2021) Roles of chitosan nanoparticles on ehrlich ascites carcinoma induced changes in some blood parameters. *Asian Oncology Research Journal*, **3**(4), 71-77.

Gokmen, V. and Senyuva, H.Z. (2006) Study of colour and acrylamide formation in coffee, wheat flour and potato chips during heating.Food Chemistry. 99, 238-243..https://doi.org/10.1016/j.foodchem.2005.06.054

Hendawy, F. Hendawy, M.D.R. (2019) Emeliorative effect of lycopene on acrylamide-induced hepatotoxicity in adult albino rats. *The Medical Journal of Cairo University*, **87**, 4129-4135. https://doi: 10.21608/mjcu.2019.76710

Horcker, B. L. and Kornberg, A. (1948) The extinction coefficients of the reduced band of pyridine nucleotides. *The Journal of biological chemistry*, **175**(1), 385–390.

Hotchkissr, R. D. (1948) A micro chemical reaction resulting in the staining of polysaccharide structures in fixed tissue preparations. *Archives of biochemistry*, **16**(1), 131–141.

Lane Peter, W. and Person, A.E.G. (1971) Dietary Requirements in the Laboratory: Animal Principles and Practice. Academic Press, London and New York, 142.

Mousa, R.M.A. (2021) Simultaneous inhibition of acrylamide formation and fat oxidation in quinoa cakes using gum Arabic supplementation coupled with fat reduction. *International journal of food properties*, **24**(1), 749–763. https://doi.org/10.1080 /10942912.2021.1924779

Nile, S.H., Baskar,V., Selvaraj, D., Nile, A., Xiao, J. and Ka, G. (2020) Nanotechnologies in food science: applications, recent trends, and future perspectives. *Nano-Micro Letters,* **12**:45. https:// doi.org/ 10.1007/s40820-020-0383-9

Oksal, E., Pangestika, I., Muhammad, T., Mohamad, H., Amir, H., Kassim, M. and Andriani, Y. (2020) In vitro and in vivo studies of nanoparticles of chitosan-Pandanus tectorius fruit extract as new alternative treatment for hypercholesterolemia via Scavenger Receptor Class B type 1 pathway. *Saudi pharmaceutical journal,* **28**(10), 1263–1275. https://doi.org/10.1016/j.jsps.2020.08.017

Omara, T., Kigenyi, E., Laker, F., Adokorach, M., Otim, G., Kalukusu, R., Musau, B., Kagoya, S., and Nakabuye, V. B. (2019) Effects of continuous deep-fat frying on the physicochemical properties of assorted brands of edible cooking oils sold in greater metropolitan kampala. *Asian Journal of Applied Chemistry Research*, **3**(2), 1-13. https://doi. org/10.9734/ajacr/2019/v3i230086

Pearson, D. (1970) The chemical analysis of food. National college of food technology, University of Reading, Weybridge, Edit by Surry, T. and Churchill, A., Ocean fishes, *Fish industry*, **4** (6): 57 - 59.

Pedreschi, F. and Moyano, P. (2005) Effect of pre-drying on texture and oil uptake of potato chips. LWT. *Food Science and Technology*, **38**(6), 599–604. DOI:10.1016/J.LWT.2004.08.008

Primožič,M., Knez, ž. and Leitgeb, M. (2021) (Bio)Nanotechnology in Food Science Food Packaging. Nanomaterials, 11, 292. https://doi. org/10.3390/nano11020292**.**

Ramli, S.S.and Rosdi, A. I .M. (2019) Effect of sugar beet pectin on oil uptake in fried banana and its acceptability. *ESTEEM Academic Journal*, **15**, 64-75. https://ir.uitm.edu.my/id/eprint/28905

Rampino, A., Borgogna, M., Bellich, B., Blasi, P., Virgilio, C.F. and Cesàro, A. (2016) Chitosan-pectin hybrid nanoparticles prepared by coating and blending techniques. *European Journal of Pharmaceutical Sciences***, 84**, 37–45. https://doi. org/10.1016/j.ejps.2016.01.004

Reeves, P.G., Nielsen, F.H. and Fahey, G.C. (1993) AIN-93 purified diets for laboratory rodents: final report of the American Institute of Nutrition ad hoc writing committee on the reformulation of the AIN-76A rodent diet. *Journal of Nutrition,* **123**, 1939-1951.

Reitman, S. and Frankel, S. (1957) A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *American Journal of Clinical Pathology,* **28**(1), 56-63. https://doi.org/10.1093/ajcp/28.1.56

Salman, A.h., El-Ghazouly, El-Sayed, D. and El Beltagy, M. (2020) Role of ascorbic acid versus silymarin in amelioration of hepatotoxicity induced by acrylamide in adult male albino rats:histological and immunohistochemical study. *International Journal of Morphology*, **38**(6), 1767-1778. http:// dx.doi.org/10.4067/S0717-95022020000601767

Singh, T., Shukla, S., Kumar, P., Wahla, V., Bajpai, V. and Rather, I. (2017) Application of nanotechnology in food science: perception and overview .*Frontiers in Microbiology*, **8**, 1501. https://doi.org/10.3389/ fmicb.2017.01501

Steel, R., Torrie, J, and Dickey, D. (1997) Principles and procedures of Statistics. A Biometrical Approach, 3rd ed., McGraw-Hill, New York, NY.

Suarez, R.B., Campanone, L.A., Garcia, M.A. and Zaritzky, N.E (2008) Comaprison of the deep frying process in coated and uncoated dough systems. *Journal of Food Engineering,* **84**, 383-393.

Suyatma, N.E., Ulfah, K., Prangdimurti, E. and Ishikawa, Y.(2015) Effect of blanching and pectin coating as pre-frying treatments to reduce acrylamide formation in banana chips. *International Food Research Journal*, **22**(3), 936-942.

Tajner-Czopek, A., Kita, A. and Rytel, E. (2021) Characteristics of French fries and potato chips in aspect of acrylamide content-methods of reducing the toxic compound content in ready potato snacks. *Applied Sciences,* **11**(9), 3943. https://doi. org/10.3390/app11093943

Uchiyama, M. and Mihara M. (1978) Determination of malondialdehyde precursor in tissues by thiobarbituric acid test. *Analytical Biochem*, **86**(1), 271-8.

Udomkun, P. and Innawong, B. (2018) Effect of pre-treatment processes on physicochemical aspects of vacuum-fried banana chips. *Journal of Food Processing and Preservation*, **42**, e13687. https:// doi.org/10.1111/jfpp.1368 7.

Watts, B., Ylimaki, G., Jeffery, L. and Elias, l. (1989) Basic sensory methods for food evaluation. IDRC, Ottawa, Ontario, Canada, 66-78.

Woodford, F. P., and Whitehead, T. P. (1998) Is measuring serum antioxidant capacity clinically useful? Ann. *Clinical Biochemistry*, **35**, 48-56. https://doi.org/10.1177/000456329803500105

Woyewoda, A.D., Shaw, S.J., Ke, P.J. and Burns, B.G. (1986) Quality indices-lipid related. In: recommended laboratory methods for assessment of fish quality: Canadian technical report of fisheries and aquatic science No. 1448, department of fisheries and oceans, Halifax, Nova Scotia.

Zeng, X., Cheng, K. W., Du, Y., Kong, R., Lo, C., Chen, F., Chu, I.K. and Wang, M. (2010) Activities of hydrocolloids as inhibitors of acrylamide formation in model systems and fried potato strips. *Food Chemistry,* **121** (2), 424-428. https://doi.org/10.1016/j.foodchem.2009.12.059

تقييم التأثيرات التكنولوجية والبيولوجية لشرائح بعض الخضروات والفواكه المقلية المعاملة بالجسيمات النانومترية للشيتوزان- بكتين

مروة عبد الكريم شعير[١]، رانيا عبد الكريم احمد[٢] ، خالد يحيى فروح[٣]

١معهد بحوث تكنولوجيا الاغذية-مركز البحوث الزراعية-جيزه-مصر

٢قسم علم الحيوان –كلية العلوم جامعة السويس –مصر

٣المعمل المركزي للنانوتكنولوجي والمواد المتقدمة-مركز البحوث الزراعية-جيزه-مصر

تعد تقنية النانوتكنولوجي مجالًا جديدًا يحول قطاع الأغذية التقليدي إلى صناعة غذائية ديناميكية ومبتكرة،\ تم إجراء هذا البحث للتحقق من كفاءة استخدام الجسيمات النانومترية للشيتوزان– بكتين (CS / Pec NPs) في تحسين جودة بعض منتجات الشرائح المقلية الشائعة (الموز والبطاطس والكسافا) , تم دراسة التغييرات في سمات جودة المنتج (PQA) للشرائح المقلية وتأثيرات تغذية الفئران على محلول (CS / Pec NPs) والمنتجات المقلية المختلفة على مدى 3 أشهر وتأثيرها من الناحية التشريحية ، المقاييس البيوكيميائية ، التغيرات النسيجية للكبد وكذلك التوضيح الهيستوكيميائى للجليكوجين. أظهرت النتائج التكنولوجية أن المعالجة قبل القلي (الغمر في محلول CS / Pec NPs)لمدة دقيقة واحدة كان لها وسيلة فعالة لتقليل تكوين مادة الأكريلاميد و امتصاص الزيت ، و اثبتت فعاليتها ايضا في تقليل مستوى المالونالدهيد في منتجات الشرائح المقلية الى(46.95% ,35.32% &1.22 mg.kg−1) لشرائح الموز المقلية ; (54.59% ,29.76 % &2.14 mg.kg−1) لشرائح البطاطس المقلية ; (49.62 % , 4.95% &1.98 mg.kg−1) لشرائح الكسافا المقلية وتحسن فى الخصائص الحسية ومظهر الصلابة. علاوة على ذلك ، أشارت النتائج البيولوجية إلى عدم حدوث أي نفوق للحيوانات بعد 3 أشهر. أظهرت النتائج ان الفئران التي تم تغذيتها على الموز المقلي والبطاطس المقلية والكسافا المقلية المعاملة بالجزيئات النانومترية للشيتوزان–بكتين درجة متقدمة من التحسن في الأنسجة الكبدية واستعادة متقدمة للجليكوجين في خلايا الكبد وتحسن معنوي في المعايير البيوكيميائية بالمقارنة بمجموعات الفئران الكنترول والتى تم تغذيتها على شرائح الموز والبطاطس والكسافا الغير معالجة. لذلك ، قد تساعد هذه الورقة البحثية مصنعي المواد الغذائية على إنتاج أطعمة مقلية صحية والحفاظ على جودة تكنولوجية أفضل.

الكلمات الافتتاحية: النانوتكنولوجي , الجسيمات النانومترية للشيتوزان–بكتين , الرقائق المقلية, التغيرات النسيجية للكبد,نسبة الجليكوجين فى انسجة الكبد.