Application of Milk Proteins Co-Precipitates Prepared Using Different Types of Minerals as Coating Materials to Reduce Oil Uptake of Fried Potato Strips

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Abstract

The edible coatings are a suitable method to decrease oil uptake in fried foods. In this study, the effects of milk protein co-precipitates aggregated using different types of minerals (CaCl2: 17 mM, FeCl3: 18 mM, ZnCl2: 18 mM, and MgCl2: 20 mM) and affected on the properties of fried potato strips were evaluated. Edible coating solutions were performed at two concentrations (%2.5 w/v) and (%5 w/v. According to the results, coated potato slices with edible coating solutions based on milk proteins co-precipitated by MgCl2 (%5) recorded higher hardness value among all the salts before frying process. Generally after frying process, coated French fries with edible coating solutions were the hardest comparable with uncoated (control) French fries, at the %2.5 w/v concentration the higher hardness value was recorded by coated French fries with CaCl2 milk protein co-precipitates and at the %5 w/v concentration the higher hardness value was recorded by coated French fries with milk protein co-precipitates ZnCl2. The experimental results showed that the coating solutions based on milk proteins co-precipitated had a positive and great effect on reducing oil uptake. In conclusion, The edible coating solutions based on milk proteins co-precipitated prepared by ZnCl2, MgCl2 at concentration %5 (w/v) reduced oil adsorption more than other coating solutions and in the same time increased the moisture content of final products sequentially compared with uncoated (control) samples. According to the sensory test, coated French fries with milk proteins co-precipitated by MgCl2 had the higher sensory evaluation degrees in appearance, color, taste and overall acceptability, while coated French fries with milk proteins co-precipitated by ZnCl2 got the highest sensory evaluation degrees for texture.

Keywords: Milk proteins, Co-precipitate, Edible coating, Potato.

1. Introduction

Milk occupies a special position among foods, as it is the only food that nature produces specifically for the nutrition of humans and animals. Milk is considered as an approximately complete food because it is a good source of protein, major minerals and fat. The main chemical milk components include water, proteins, fats, carbohydrates, minerals, vitamins and enzymes [1]. The introduction of cow’s milk into the diet has a very long tradition, cow milk is the most common consumed milk, where 85% of the global milk production is derived from cows, followed by other species, e.g. buffalo (11%), goat (2.3%), sheep (1.4%), and camel (0.2%) [2,3].

Edible films are self-standing structures in nature [4]. Biopolymers are widely implemented and can be used as coatings and films. Coating involves the formation of a cover directly on the surface of food products, whereas films are structures that are used separately after formation. Proteins are the most promising biopolymers for the production of packaging materials. Proteins are hetero-polymers consisting of α-amino acids as monomeric units. The combinations of 20 amino acids to form a protein sequence allow for an almost unlimited number of various polymer chains with different physical and chemical properties. Proteins also contain a large number of functional groups that can be changed enzymatically, chemically, or physically for varying the properties of the films [5]. Milk proteins are good candidate to form biodegradable films [6,7]. Milk proteins, consisting of whey proteins and caseins, which are important to human nutrition, but are also gaining importance as a natural product polymer with the potential to be utilized as encapsulation carriers for nutraceuticals for different foods and biotechnological applications. Packaging materials composed of milk proteins could be improved by the food industry and be used as active edible packaging to improve the quality and safety characteristics of food products. Systems of milk protein-based vehicle that exist on their own or as part of new sustainable packaging forms are expected to
become a key strategy for launching safe food products, and thus have the potential to increase profit margins for the food industry [8]. The milk proteins function is an essential feature utilized in the food industry. Proteins of milk have the ability to bind electrostatically divalent metal ions. The hydrophilic and hydrophobic domains existent in milk proteins makes them great modules for the specific-site delivery of different bioactive analyses [9]. The milk proteins form covalent conjugates and electrostatic complexes with hydrophobic sites, preserve bioactive compounds via shielding impact, biodegradable in nature, agreeable with the non-toxic system, and support access to micronutrients and bioactive compounds [10]. Additionally, proteins of milk contain active binding sites such as (phosphoserine sites) also they have excellent inclination to bind many bivalent metals ions like magnesium, calcium, gold, copper, zinc, silver, iron, and this reaction depends on the kind of metal, environment conditions and the available sites in protein [11]. The production of co-precipitates from milk was created because of the high nutritional value and the required whey proteins functional properties in addition to the need to enhance the amount of resulting proteins [12]. The milk protein co-precipitate can be defined as the product containing both heat denatured whey proteins and casein. The milk protein co-precipitates are generally made by heating milk at a temperature above (60 °C). Milk protein complex could be precipitate immediately after heat treatment or it can be cooled and then precipitated. The precipitation is obtained either with acid, divalent ions (e.g. calcium), or other ions that affect the solubility of the complex. During preparation of co-precipitate, (96%) of cow milk proteins and (97%) of sheep milk proteins were recovered [13]. The functional and textural properties of resulting milk protein co-precipitates are completely different from caseins and whey proteins and this can be used to develop a new industrial application for dairy products and edible coating and films is one of them. The shelf life of fresh fruits and vegetable commodities after harvesting can be extended by the application of coatings and cold storage [14]. The potato, Solanum tuberosum L., was originally cultivated in Peru and from there it spread to Spain, Portugal and to other parts of Europe in the late 1500. Within the next two centuries, it was exported to America, Australia, China and elsewhere [15]. It is a plant of the Solanaceae family and is one of the most popular vegetable crops in the world. It is also one of the most famous foods. Potato has a high nutritional value. Generally, 100 grams of fresh potatoes contains 22-25 g of dry matter which provide 76 kcal; include17g carbohydrate, 2g Protein, 0.5g fiber, 0.1g Fat and 0.9g ash. Potato varieties are divided into nine main groups including (Russet potato, Red potato, White potato, Yellow potato, Purple potato, Fingerling potato, Petite potato, Yukon gold potato, New potato) [16] and [17]. It was studied that new potato varieties especially Lady Rosette (LR) has a strong potential for chips due to their good physicochemical characteristics, less oil absorption and high storage stability [18]. Fried food is common food around all the world and cover a wide variety of products [19]. Thus, many studies have been done to control or minimize oil content on the final fried products and improving the frying process [20]. However, the fried foods include significant amount of fat. For instance, in potato chips rate of oil in a total food product by weight is (1/3). Recently, most people has recognized the desirability of decreasing fat content of deep-fried products. Therefore, consumer trends are moving toward healthier food and low-fat products, which creating the need to develop technologies to decrease the amount of oil in the fried products [21]. Potato is a main and major agricultural crops around a whole world. Millions of people who have various cultural backgrounds consumed potato every day. Potatoes are cultivated in nearly (80%) of all countries and worldwide production stands in excess of 300 million tons annually. French fries/ finger chips are one of the most popular processed potatoes [22].

Currently, there are no reports in the literature on the effect of milk protein co-precipitates prepared using different types of salts (Ca$^{2+}$, Fe$^{3+}$, Zn$^{2+}$, Mg$^{2+}$) on the properties of edible coatings, therefore, this study aimed to preparation of milk protein co-precipitates from cow milk using different types of minerals (Ca$^{2+}$, Fe$^{3+}$, Zn$^{2+}$, Mg$^{2+}$) and investigate the effect of milk protein co-precipitates edible coating on the physicochemical properties, fat content and sensorial characteristics of potato French fries.

2. Material and Methods

2.1 Milk samples

Bulk cow’s milk were collected from 6 cows through the period October 2019 to February 2020 in Halabja Governorate/ Iraqi Kurdistan region. Cow’s milk was skimmed by centrifugation on 2400 g for 15 minutes at 5°C.

2.1.1 Preparation of milk proteins co-precipitate by using the different kinds of salts

The Preparation were done according to Al-Saadi and Deeth [23] with some modification. 100 milliliters of cows skimmed milk samples were subjected to pre-heat treatment for 20 minutes at 90 Celsius in a water bath and cooled to 22 Celsius. Calcium chloride , Ferric chloride, Zinc chloride, Magnesium chloride were added to each milk sample at 22 Celsius at concentrations of 17 mM, 18 mM, 18 mM and 20 mM respectively and mixed thoroughly. The resultant milk samples were heated up to 90 Celsius and left undisturbed at this temperature for 20 minutes to produce milk gels. The resulting gel was
cooled to room temperature, catted to remove whey and filtered through Whatman No. 1 paper, washed with water for 3 times and freeze dried.

### 2.1.2 SDS-Polyacrylamide Gel Electrophoresis

Two types of SDS-PAGE were done with and without 2-mercaptoethanol. Both of them had the same steps for preparation, except in the SDS-PAGE without Mercaptoethanol, the Mercaptoethanol was not added into the sample buffer. The Laemmli [24] method was used for samples analysis with a few changes.

### 2.2 Preparation of coating solutions

100 ml of coating solutions were prepared via mixing milk protein co-precipitated prepared using CaCl$_2$, ZnCl$_2$, FeCl$_3$ and MgCl$_2$ in two concentration (%2.5 w/v) and (%5 w/v) with distilled water (80 ml) and pH was adjusted to (8 - 8.5) using Sodium hydroxide (2N). After stirring constantly and complete solubility, the pH adjusted to 8 and glycerol (5.0 % w/v) was added. Then each concentration of coating solutions was completed to (100 ml) by adding distilled water. Each mixture was heated at (85 Celsius for 20 minutes), with stirring continuously. Next, the mixtures were homogenized for 3 minutes. The solutions were filtered within a piece of cheesecloth and vacuum-degassed for 40 minutes and used for coating intended (Potato).

### 2.3 Post-Harvest of Potato

Around 40 kg of potato tubers (Lady Rosetta cultivar) were obtained from the fields in Gokhlan village that located in Penjwen district in Sulaimani Governorate/Iraqi Kurdistan region-Iraq. Tubers were harvested at the date (10th October, 2020), and potatoes stored in the lab cooler at (5±1) °C for 2 weeks before using for the experiment.

### 2.3.1 Sample treatment

Tubers were cleaned with distilled water before paring and cut manually into 8 x 8 x 60 mm strips by using blade insert cutting machine (One step precision Cutting, Nicer dicer plus/China). Then, the slices were dipped in a 0.05% ascorbic acid solution, with a 2:10 potato slices/acid solution rate, for 15 minutes to evade enzymatically browning. When the time was over, an extra amount of solution was eliminated by a disposable cloth [25].

### 2.3.2 Coating applications

This procedure was done in food quality control lab at Technical College of Applied Sciences /Sulaimani Polytechnic University. Potatoes slices were divided into nine groups for treatments depending on edible coating solutions includes milk proteins co-precipitated by (CaCl$_2$, ZnCl$_2$, FeCl$_3$, MgCl$_2$) in two concentration (%2.5 w/v) and (%5 w/v) and uncoated slices as a control. Each group was triplicated. The edible coating of potatoes was done relying on the methodology suggested in [26]. Concisely, each potato slice was dipped in the coating solutions for 15 seconds. Then, the potatoes were drained for (45-55) minutes under a fan at room temperature to ensure dry-ness [27].

### 2.3.3 Process of frying

This process was done according to the methodology proposed in [28], with some changes. An electric fryer (CLATRONIC Fritteuse FR 2766: 2L: 1600 Watt / Germany) was used in this process. Each treated sample was dipped in two-liter refined sunflower oil (1:21 strips: oil ratio) and was fried at 180°C for 10 minutes. The oil was changed after frying of each lot. Then the French fries were allowed to cool at room temperature and evaluated for sensory quality. Subsequently, the fried slices were analyzed for Hardness, oil uptake and moisture retention.

### 2.3.4 Study the characteristics of fried potatoes

The performed tests were: Hardness, oil uptake and moisture retention. The Hardness parameter was done for coated and uncoated sample groups before and after frying, while both parameters oil uptake and moisture retention were measured after frying for coated and uncoated sample groups.
2.3.4.1 Measurement of Hardness (N)

The hardness of coated and uncoated samples was measured using (Texture Analyzer BROOKFIELD) as explained in [29] utilizing 4 mm probe diameter and 0.2 Kg load cell, which was moving at the speed (1 mm/sec-1) with a depth of 5 mm.

2.3.4.2 Oil uptake in potato fries

The oil content in samples was determined using Soxhlet instrument (Soxhlet Gerhardt/Germany) utilizing hexane as solvent [30] and [31].

2.3.4.3 Moisture content

This process was conducted using oven drying method at 105°C for 24 h as described in [32].

2.3.5 Sensorial analysis

The sensory quality of (fresh potatoes, coated and uncoated potatoes) was performed after the frying operation. The evaluation was done by 8 panelists, their ages were between (21 and 55) years. Depending on the method expressed in [33], the samples were analyzed for (appearance - color - taste - texture, and overall acceptability) from (1 to 9) grade as follows: (1= extremely dislike, 9= extremely like). The result acquired for different quality parameters were written and the average values of triplicate observations were recorded.

2.3.6 Statistical analyses

The experiment was done using ANOVA table completely randomized design (CRD) with 3 Replication, and the XLSTAT Pro. 9 software was used for data analysis. The differences between means were determined by Duncan’s multiple ranges at P ≤ 0.05.

3. Results and Discussion

3.1 SDS–PAGE of milk proteins co-precipitates

SDS-PAGE with and without mercaptoethanol for milk proteins co-precipitate samples prepared using 17 mM CaCl₂, 18 mM FeCl₃, 18 mM ZnCl₂ and 20 mM MgCl₂ is shown in (Figure 1). The treatment of cow milk proteins with salt ions and heat lead to the formation of new protein bands. These new bands were high-molecular-weight bands resulting from cross-linked proteins and appear at molecular weights greater than those of the caseins. The changes in the electrophoretic patterns of casein and whey proteins treated with salt ions and heat appeared to be different under ME and without ME conditions. The electrophoretic patterns indicate that the density of high-molecular-weight milk protein bands in presence of ME (Figure 1. a) was lower than their density in absence of ME (Figure 1.b) this result disagrees with Al-Saadi, et al. [34] that studied the effect of heat and transglutaminase on solubility of goat milk protein-based films. Ions force interactions had the major role in milk proteins cross-linking with ME because disulphide bonds had no role in milk proteins cross-linking because they were broken by ME, while ions force + disulphide bonds had great role in milk proteins cross-linking without ME (Figure 1. b) it can be concluded that disulphide bonds play a major role in cow milk protein cross-linking during heat treatment and addition of salt ions.

SDS-PAGE (Figure 1.a &b) exhibit that cross-linking proteins was not detected in raw milk, while in (2, 3, 4, 5) there were high molecular bands detected in lanes with heat-treated cow milk proteins with CaCl₂, FeCl₃, ZnCl₂, and MgCl₂ respectively. The appearance of these bands indicates that large protein aggregates accumulated and high-molecular-weight proteins are noticeable on SDS-PAGE gels. From these results, it can be concluded that the two heat treatment and salt ions in lanes (2, 3, 4, 5) have great effect on cow milk proteins. In step one, first heat treatments led to denaturation of whey proteins and a part of calcium which presented naturally in protein changed from the soluble to the colloidal status. In addition, whey protein also reacts with casein for forming whey–casein aggregation[35]. In step two, the denaturation of milk proteins was finished. After addition of salts + second heat treatment, the salt ions interact with proteins and neutralized the negative charges of milk proteins. The reaction of metal salt with a protein usually leads to an insoluble metal protein complex. This result appeared that milk proteins have the ability to bind electrostatically divalent metal ions [9] because it contains active binding sites such as (phosphoserine sites) which have an excellent inclination to bind many bivalent metals ions like magnesium, calcium, zinc, iron [11,36]. The binding of milk proteins with salt ions depends on the kind of metal ions, environment conditions and the available sites in protein. Figure (1 b) show that milk proteins of have a higher affinity for iron but it has a lower affinity for magnesium and this result agree with [37] which...
demonstrates that the proteins of milk have higher affinity for iron followed by zinc, calcium, and magnesium in descending order. The aggregations of milk protein in lane (3) is more than lanes (2, 4, 5) sequentially because Fe³⁺ has three positive charges for this reason it has a capacity to link with three negative groups of casein, while (Ca²⁺, Zn²⁺, and Mg²⁺) have two positive charges sequentially they have ability to link with two particles of casein. Additionally, Figure 1 exhibited that the crosslinking of milk proteins co-precipitate prepared using calcium (2) is higher than proteins co-precipitate prepared using magnesium (5), and this can be explained by the facts that in a serum phase, some of Ca²⁺ (around 0.5 mmol L⁻¹ in milk) are associated with α-lactalbumin, while Mg²⁺ does not bind to this protein [38] and both of ions have various binding sites upon caseins; phosphoserine for Ca²⁺, and aspartic and glutamic acids for Mg²⁺. It was studied that one of Mg²⁺ binding sites is similar with Ca²⁺ binding site but the binding of Mg²⁺ is weaker rather than that of Ca²⁺ [39]. We can conclude that all milk proteins co-precipitate samples prepared using CaCl₂, FeCl₃, ZnCl₂ and MgCl₂ contain most of the whey proteins (α-Lactalbumin (α-La) and β-Lactoglobulin (β-Lg)) and caseins. These all returns to casein are saturated by enough amount of ions binding to casein and have time to react with denatured whey protein in suitable temperature. These results are in good agreement with Al-Saadi and Deeth [23] that showed preparation co-precipitate from sheep milk and with the study of Ali and Al-Saadi [13] which prepared milk proteins co-precipitate using zinc and ferrous salts.

![Figure 1. SDS-PAGE for milk proteins co-precipitate samples. (a) with Mercaptoethanol (b) without Mercaptoethanol (1) raw milk proteins and (2, 3, 4, 5) are milk proteins co-precipitate samples prepared using 17 mM CaCl₂, 18 mM FeCl₃, 18 mM ZnCl₂ and 20 mM MgCl₂ respectively.]()
ZnCl$_2$ at the concentration (%5 w/v) had a lower value of 22.68 N. These results were higher than the result obtained by Zheng and Moreira [44] who investigated the feasibility of using ultrasound-vacuum impregnation to enhance the texture and reduce the oil content of potato chips. Figure (4) demonstrated a significant difference $P \leq 0.05$ between the results of hardness for uncoated (control) and coated French fries with edible coating solutions based on milk proteins co-precipitated after frying process at 180°C for 10 min. In general, among all samples the coated French fries with edible coating solutions based on milk proteins co-precipitated prepared using ZnCl$_2$ at the concentration %5 had a higher value of hardness (3.65 N) whereas the coated French fries with edible coating solutions based on milk proteins co-precipitated prepared using FeCl$_3$ at the concentration %5 had the lowest value (2.637 Newton (N)). The results obtained in the present study are in agreement with those reported by [45] who evaluated the effect of the application of an edible coating developed from whey proteins and rosemary extracts on potato chips the hardness values ranged between 0.5 and 5.7 N, it is also corresponded with the result that reported by [46] who analyzed this parameter in potatoes of the Atlantic variety, under traditional frying conditions, obtaining values of compression force between 3 and 4 N. In a similar way, [47] reported hardness values between 3 and 5 N for French fries with added natural extracts. Generally depending on these results, coated French fries with edible coating solutions based on milk proteins co-precipitated were harder than the uncoated (control) French fries. Because the texture of fried potato products depends on the building elements present in the cell walls. The peeling process of potato tubers affects the decrease of the pectic substances content as compared to the raw material. The texture of French fries produced from the tubers of higher pectin content is more firm than that of the tubers with lower contents of water-soluble pectins and protopectins, for this reason, the researchers Zheng and Moreira[44] and Tajner-Czopek [48] found that using minerals salt ions to potato strips prior to frying prevented further loss of the pectic substances and resulted in French fries with markedly improved texture. On the other hand, a positive effect of the milk proteins co-precipitated on the hardness of the coated French fries was observed. In this sense, milk proteins co-precipitated content in the coating lead to greater values of the hardness in the coated French fries. It could be explained due to the milk protein has the capacity to form gel when subjected to heating temperatures. It increases the retention of water and the elasticity of the final product [49] and makes the food harder and less crispy [45]. Some authors affirm that proteins or the concentration of proteins directly related to the hardness of the gels and, therefore, of the final product [50].

![Figure 2](image)

**Figure 2.** Hardness of uncoated and coated potato fries with edible coating solutions based on milk proteins co-precipitated prepared by (CaCl$_2$, ZnCl$_2$, FeCl$_3$ and MgCl$_2$) at the concentration (%2.5 w/v) and (%5 w/v) before frying process. *Con. = Control (uncoated slices) *N = Newton. Different letters indicate presence of statistical differences at the level of $P \leq 0.05$.

![Figure 3](image)

**Figure 3.** Hardness of uncoated and coated French fries with edible coating solutions based on milk proteins co-precipitated prepared by (CaCl$_2$, ZnCl$_2$, FeCl$_3$ and MgCl$_2$) at the concentration (%2.5 w/v) and (%5 w/v) after frying process at 180°C for 10 min. *Con. = Control (uncoated slices) *N = Newton. Different letters indicate presence of statistical differences at the level of $P \leq 0.05$. 

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3.2.2 Oil uptake in French fries

The results in Figure (4) showed that there are significant differences between the outcomes of oil content for uncoated (control) and coated French fries with edible coating solutions based on milk proteins co-precipitated after frying process at 180°C for 10 min. The highest oil content value was obtained from uncoated (control) French fries which was 26.24%, while the lowest oil uptake was obtained with French fries coated with %5 milk proteins co-precipitated prepared using ZnCl₂ which was 9.85%. There were a decrease in oil uptake values to 22.69, 21.77, 17.47, 16.68, 15.25, 12.95 and 10.70% in French fries coated with milk proteins co-precipitated prepared using FeCl₃ %5, CaCl₂ %2.5, MgCl₂%2.5, CaCl₂%5, ZnCl₂%2.5, FeCl₁ %2.5 and MgCl₂%5 respectively. In the (%5 w/v) concentration the highest oil adsorption was obtained by coated French fries with FeCl₃ but the lowest oil adsorption was obtained by coated French fries with ZnCl₂. The edible coating solutions based on milk proteins co-precipitated by (ZnCl₂, MgCl₂) at the concentration (%5 w/v) reduced oil adsorption more than other coating solutions. The significant oil reduction is supported by previous study of Trujillo-Agudelo, et al., who used edible coating developed from whey proteins and rosemary extracts on the reduction of fat in potato chips, the fat content ranged between 8 and 31% [45]. Jafarin and Mohammad nejad investigated the effect of propolis coating on oil uptake and quality properties of fried potato (Solanum tuberosum) strips [51]. Angor [52] studied the influence of whey protein and whey protein isolate as edible coating films on potato pellets chips to reduce oil uptake during deep frying, found that the 5% was the most effective level in reducing fat uptake for both coating films. The results showed that the edible coating solutions based on milk proteins co-precipitated have a positive and great effect on reducing oil uptake. The use of metal ions is related to oil reduction in fried products by maintaining the cell integrity [53]. Kim and Moreira found that by soaking potato strips in 3% w/w NaCl solution for 5 min, decreased oil absorption by 35% compared to the untreated samples[54]. The retention of metal ions by the plant cell wall depends not only on cell wall structure, but also on starch content, type and concentration of treated metal ions, thus limitations exist in the absorption of metal ions [55,56,57,58]. Therefore, metal ions help to decrease oil uptake in fried food [59]. On the other hand, [60] concluded that addition of different proteins at different concentrations to the batter decreased the oil content of the final deep-fried product. Less oil absorption may be related to the formation of covalent links within films during heating. Also reported that, the potential formation of intermolecular disulfide cross-links in whey protein films might have improved the barrier properties of the WPI-added batter for water vapor. The reduced oil uptake may also be related to thermal gelation and the film-forming ability of proteins. Varela and Fiszman reported that using different coating film ingredients have been proved to be effective in reducing the amount of oil absorbed by fried food [61]. It was reported that using many edible coating films were reduced fat absorption and improved moisture retention in starchy products and poultry products [62]. The microstructure of the crust is the main determining factor for oil uptake which takes place by a capillarity mechanism. Coating make the surface stronger and more brittle with fewer small voids which reduces evaporation and leads to less oil uptake and alter the water holding capacity by trapping moisture inside and preventing the replacement of water by oil [63]. [64] found that potato chips with milk protein coating exhibited less oil. In addition, [65] found that the fat absorption in plant structures decreases at frying temperatures between 180 and 200°C, a range close to the frying temperatures of the present study. In summary, oil absorption is influenced by different factors such as the time and temperature of frying, the quality of the oil, the previous treatments, and the composition (both the coating and the food) [66].

![Figure 4](image)

**Figure 4.** Oil content of uncoated and coated French fries with edible coating solutions based on milk proteins co-precipitated prepared by (CaCl₂, ZnCl₂, FeCl₁ and MgCl₂) at the concentration (%2.5 w/v) and (%5 w/v) after frying process at 180°C for 10 min. *Con. = Control (uncoated slices). Different letters indicate presence of statistical differences at the level of P ≤ 0.05.*
3.2.3 Moisture content

Figure (5) showed the differences (P ≤ 0.05) between moisture content for uncoated (control) and coated French fries with milk proteins co-precipitated solutions at the concentrations 2.5 and 5% after frying process at 180°C for 10 min. The highest moisture content was observed in French fries coated with 5% milk proteins co-precipitated prepared using ZnCl₂ which was 60.84%, while the lowest moisture content was for the treatment prepared using 2.5% ZnCl₂ which was 55.02%. All the moisture content for other treatments were ranged between these 2 values. These results of moisture content were nearly similar to the result found by [67] who used zinc and hydrocolloid on moisture content in fried potato slices ranged which were 65.1 - 58.7%. On the other hand, it was higher than the result of Trujillo- Agudelo, et al. who utilized whey proteins for coating which ranged from 4.6 to 33.4% [68].

Coating with milk proteins co-precipitated by ZnCl₂ and CaCl₂ at the concentration (%5 w/v) increased the moisture content of final products sequentially compared with uncoated (control) samples. This result agrees with the result found by [69], who found that protein coating apparently functioned to reduce water loss during frying which, in turn, lessened oil absorption [64]. Proteins used in this study might exert their effect due to their surface properties which altered the water holding capacity and consequently affect oil uptake as a result of strong hydrogen bonding between water molecules with proteins [67]. In contrast, Hamarashid observed the highest value of moisture content was noticed in potato samples pre-treatment with calcium chloride and starch solution and this was due to the oppositely relationship between the content of moisture and oil. Oil contents decreased with increasing moisture content[22]. Higher oil uptake ratio caused by lower moisture content. Increasing the moisture content of potato strips by pre-frying treatment is the one of efficient way to reduce oil uptake in the final fried product [68]. Various surface coating materials such as protein, powdered bread crumbs, starch, carrageenan, and their combinations were used to reduce moisture loss and fat uptake of chicken meat balls during deep fat frying [69]. The increasing in moisture content and reduction in fat absorption were due to using coating films agreed with that obtained by [70]. The influence of different levels of whey protein and whey protein isolate as coating films in reducing fat uptake which led to a higher retention of moisture content for deep fried potato pellets chips [52].

According to the sensory test 90% of panelists differentiated the coated from uncoated samples in terms of color, taste, texture, visual appearance, and overall acceptability, however there were significant differences P ≤ 0.05 among the samples during comparison process. Qualitatively, the results of the preference sensory test revealed that coated French fries except coated samples with Fe³⁺ were considered more acceptable and better than uncoated (control) samples with respect to all parameters. The samples coated with milk proteins co-precipitated by Fe³⁺ was less acceptable compared to all samples because they had a dark color Figure (6a). Coated French fries with milk proteins co-precipitated by MgCl₂ at the concentration (%5 w/v) and (%2.5 w/v) respectively had the higher sensory evaluation degrees , and were more acceptable than uncoated (control) and all coated samples in appearance, color, taste and overall acceptability, while Coated French fries with milk proteins co-precipitated by ZnCl₂ at the concentration (%5 w/v) got the highest sensory evaluation degrees for texture Figure (6c).
Figure 6. Sensory evaluation degrees of uncoated and coated French fries with coating solutions based on milk proteins co-precipitated prepared by (CaCl$_2$, ZnCl$_2$, FeCl$_3$ and MgCl$_2$) at the concentration (%2.5 w/v) and (%5 w/v) after frying process at 180°C for 10 min. (a) color (b) taste (c) texture, (d) appearance (e) overall acceptability.

Conclusion

Treatment of cow milk proteins with salt ions (CaCl$_2$, ZnCl$_2$, FeCl$_3$ and MgCl$_2$) and heat, lead to the formation of new protein bands. These new bands were high-molecular-weight bands resulting from cross-linked proteins and appear at molecular weights greater than those of the caseins and whey. Edible coating solutions were prepared based on milk proteins co-precipitated in two concentrations (2.5 and 5 %) and were used for potato strips coating. Generally after frying process, coated French fries with edible coating solutions based on milk proteins co-precipitated were harder, lower oil uptake, higher moisture content and sensory more acceptable than uncoated (control) fries.

References

[1] L. Anetta, M. Peter, G. Agnieszka and G. Jozef, 2021, “Concentration of selected elements in raw and ultra heat treated cow milk”, Journal of microbiology, biotechnology and food sciencespp. 795-802.
[2] V. Gantner, P. Mijić, M. Baban, Z. Škrtić and A. Turalija, 2015. “The overall and fat composition of milk of various species”, Mljekarstvo/Dairy, 65(4).
[3] A. G. Mohamed, O. A. E. H. Ibrahim, W. A. Gafour and E. S. Farahat, 2021, "Comparative study of processed cheese produced from sheep and cow milk", Journal of Food Processing and Preservation, 45(1), p.e15003.

[4] G. Sakti and M. M. S. Ganesh, 2021, "BIO EDIBLE COATING ON CUCUMBER BY USING LEMON PEEL, COCONUT MILK AND CHINA GRASS", EPRA International Journal of Multidisciplinary Research, 7(5), pp. 286-291.

[5] A. Lisitsyn, A. Semenova, V. Nasonova, E. Polischuk, N. Revutskaya, I. Kozyrvev and E. Kotenkovala, 2021, "Approaches in Animal Proteins and Natural Polysaccharides Application for Food Packaging: Edible Film Production and Quality Estimation", Polymers, 13(10), p. 1592.

[6] S. Pirsa and K. Aghbolagh Sharifi, 2020, "A review of the applications of bioproteins in the preparation of biodegradable films and polymers", Journal of Chemistry Letters, 1(2), pp. 47-58.

[7] S. S. Hauzourkam and B. Mohanty, 2020 "Functionality of protein-Based edible coating" Journal of Entomology and Zoology Studies 8(4): 1432-1440.

[8] D. Daniloski, A. T. Petkoska, N. A. Lee, A. E. D. Bekhit, A. Carne, R. Vaskoskka and T. Vasiljevic., 2021, "Active edible packaging based on milk proteins: A route to carry and deliver nutraceuticals", Trends in Food Science & Technology.

[9] A. Agarwal, A. K. Pathera, R. Kaushik, N. Kumar, S. B. Dhull, S. Arora and P. Chawla, 2020"Succinylation of milk proteins: Influence on microparticle binding and functional indices", Trends in Food Science & Technology, 97, pp. 254-264.

[10] M. A. Syama, S. Arora, C. Gupta, A. Sharma and V. Sharma, 2019, "Enhancement of vitamin D2 stability in fortified milk during light exposure and commercial heat treatments by complexation with milk proteins", Food Bioscience, 29, pp. 17-23.

[11] B. G. Shilpashree, S. Arora and V. Sharma, 2015, "Preparation of iron/zinc bound whey protein concentrate complexes and their stability", LWT - Food Science and Technology, 66, pp. 514-522.

[12] M. H. Ala’idatt, G. J. Al-Rabadi, I. Alli, K. Ereiej, T. Rababah, M. N. Alhamad and P. J. Torley, 2013,"Protein co-precipitates: A review of their preparation and functional properties", Food and Bioproducts Processing, 91(4), pp. 327-335.

[13] Z. K. Ali and J. M. Al-Saadi, 2020, "Milk Proteins Co-precipitate Preparedusing Zinc and Ferrous Salts", Indian Journal of Public Health, 11(04), p.1419.

[14] S. Shah and M. S. Hashmi, 2020, "Chitosan-aloe vera gel coating delays postharvest decay of mango fruit", Horticulture, Environment, and Biotechnology, 61, pp. 279–289.

[15] H. Ragab, H. Abdel-Aal, F. Kizito and M. Youssef, "Quality Attributes of French Fries: Factors Affecting Thereon A Review", 2019.

[16] S. A. A. Safraiy, 2015 "Physicochemical Study of Some Potato Varieties and Quality of Their Processed Chips", MSc. Thesis, Collage of Agriculture, University of Tikrit.

[17] B. Y. A. Abdullah and S. A. A. Safraiy, 2015, "Study of chemical and physical characteristics for some potato cultivars available locally and evaluation of chips produced from them", Food Science. 4(15), pp.157–166.

[18] A. Nawaz, A. Danish, S. W. Ali, H. Muhammad Shabbaz, I. Khalifa, A. Ahmed, S. Irshad, S. Ahmad and W. Ahmed, 2021, "Evaluation and storage stability of potato chips made from different varieties of potatoes cultivated in Pakistan", Journal of Food Processing and Preservation, p.e15437.

[19] Z. S. Zolfaghari, M. Mohebbi and M. H. Khodaparst, 2001” Quality changes of donuts as influenced by leavening agent and hydrocolloid coatings”, University of Mashhad, Department of Food Science and Technology, Iran.

[20] P. Garcia- Segovia, A. M. Urbano- Ramosa, S. Fiszman and J. Martinez- Monzo, 2016,"Effects of processing conditions on the quality of vacuum fried cassava chips (Manihot esculenta Crantz)", J Food Science and Technology, 69, pp. 515-521.

[21] W. Amboon, W. Tulyanath and J. Tattiyaakul, 2012, "Effect of Hydroxypropyl Methylcellulose on Rheological Properties, Coating Pickup, and Oil Content of Rice Flour-Based Batters", J Food Bioproducts Technology, 5, pp. 601–608.

[22] S. H. Hamarashid, 2020, "Effects of Pre-Frying Treatment on Decreasing Oil Absorption During Deep Fat Frying Process", Tikrit Journal for Agricultural Sciences, 20(1), pp. 88-96.

[23] J. M. AL-SAADI and H. C. Deeth, 2011, “Preparation and functional properties of protein coprecipitate from sheep milk”, International journal of dairy technology, 64(4), pp.461-466.

[24] U.K. Laemmli, 1970, “Cleavage of structural proteins during the assembly of the head of bacteriophage T4”, nature, 227(5259), pp.680-685.

[25] L. Yu, J. Li, S. Ding, F. Hang and L. Fan, 2016, "Effect of guar gum with glycerol coating on the properties and oil absorption of fried potato chips", Food Hydrocolloids, 54, 211–219.

[26] D.De Grandi Castro Freitas, S. A. G. Berbati, P. Prati, F. M.Fakhouri, F. P. Collares Queiroz, and E. Vicente, 2009, "Reducing fat uptake in cassava product during deep-fat frying", Journal of Food Engineering, 94 (3), pp. 390–394.

[27] C. Han, Y. Zhao, S.W.Leonard, and M.G.Traber, 2004, "Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (Fragariax ananassa) and raspberries (Rubus ideus)”, Postharvest Biology and Technology, 33(1), pp.67-78.

[28] S. Rimac-Brcin, V. Lelas, D. Rade and B. Simundic, 2004, "Decreasing of oil absorption in potato strips during deep fat frying", Journal of Food Engineering, 64(2), 237–241.

[29] “AOAC Official Methods of Analysis, 2002”, 17th ed, Washington DC, USA., Association of Official Agricultural Chemists.

[30] A. Szydłowska-Czerniak and D. Rabiey, 2020 "Effect of new antioxidants: phenolipids on quality of fried French fries and rapeseed oil", Journal of Food Science and Technology., pp.1-10.

[31] AOAC Official Methods of Analysis, 2012”,19th Edition, Washington DC, Association of Official Analytical Chemists.

[32] "AOAC Official Methods of Analysis,1984",14th Edition, Washington DC, Association of Official Analytic Chemists, Method 28.074.

[33] M.A. Amerine, R.M. Pangborn and E.B. Roessler., 1965"Principles of sensory evaluation of food”, New York: Academic Press.
[34] J. S. Al-Saadi, K. A. Shaker and Z. Ustunol, 2014, "Effect of heat and transglutaminase on solubility of goat milk protein-based films", International Journal of Dairy Technology, 67(3), pp. 420-426.

[35] A. A. Elfagm and J. V. Wheelock, 1978, "Heat interaction between alpha-lactalbumin, beta-lactoglobulin and casein in bovine milk", Journal of Dairy Science, 61, pp. 159–193.

[36] B. G. Shilpsphee, S. Arora, S. Kapila and V. Sharma, 2018, "Physicochemical characterization of mineral (iron/zinc) bound caseinate and their mineral uptake in Caco-2 cells", Food Chemistry, 257, pp. 101-111.

[37] M. Philippe, Y. Le Graet and F. Gaucheron, 2005, "The effects of different cations on the physicochemical characteristics of casein micelles", Food Chemistry, 90 (4), pp. 673-683.

[38] Y. Hiroaka, T. Segawa, K. Kuwajima, S. Sugai and N. Murai, 1980, "a-Lactalbumin: a calcium metallo-protein", Biochemical & Biophysical Research Communications, 93, pp. 1098-1104.

[39] H. E. Oh and H. C. Deeth, 2017, "Magnesium in milk", International dairy journal, 71, pp. 89-97.

[40] A. K. Thyo, H. J. Martens and O. B. Lyshede, 1998, "Texture and microstructure of steam cooked, vacuum packed potatoes", Journal of Food Science, 63(4), pp. 692-695.

[41] A. Andersson, V. Gekas, I. Lind, F. Oliveira, R. Øste and J. M. Aguilfira, 1994, "Effect of preheating on potato texture", Critical Reviews in Food Science & Nutrition, 34(3), pp. 229-251.

[42] S. Neynies, N. Ooms and J. A. Delcour, 2020, "Transformations and functional role of starch during potato crisp making: A review", Journal of Food Science, 85(12), pp. 4118-4219.

[43] F. Nourian and H. S. Ramaswamy, 2003, "Kinetics of quality change during cooking and frying of potatoes: Part I. Texture", Journal of food process engineering, 26(4), pp. 377-394.

[44] T. Zheng and R. G. Moreira, 2020, "Magnesium ion impregnation in potato slices to improve cell integrity and reduce oil absorption in potato chips during frying", Heliyon, 6(12), p.e05834.

[45] S. Trujillo-Castro, A. Osorio, F. Gómez, J. Contreras-Calderón, M. Mesías-García, C. Delgado-Andrade, F. Morales and O. Vega-Castro, 2020, "Evaluation of the application of an edible coating and different frying temperatures on acrylamide and fat content in potato chips", Journal of Food Process Engineering, 43(5), p.e13198.

[46] C. Granda, R. G. Moreira and S. E. Tichy, 2004, "Reduction of acrylamide formation in potato chips by low-temperature vacuum frying", Journal of Food Science, 69, pp. 405–411.

[47] G. Morales, M. Jimenez, O. Garcia, M. Remedios and C. Ignacio, 2014, "Effect of natural extracts on the formation of acrylamide in fried potato-toes", Food Science and Technology, 58(2), pp. 587–593.

[48] A. Tajner-Czopek, 2003, "Changes of pectic substances concentration in potatoes and French fries and the effect of these substances on the texture of the final product", Food/Nahrung, 47(4), pp. 228-231.

[49] D. Yamul, 2008 "Propiedades de geles de concentrado de proteínas de lactosauro, miel y harina", Tesis de Doctorado, Centro de Investigación y Desarrollo en Ciencia de Alimentos, Universidad Nacional de La Plata, Argentina.

[50] M. J. Baborowska, P. J. Mollet, M. Szadkowski and N. Murai, 2017, "Magnesium ion impregnation on potato texture", Critical Reviews in Food Science and Nutrition, 57(1), pp. 1-16.

[51] T. J. Beveridge and R. G. Murray, 1976, "Uptake and retention of metals by cell walls of Bacillus subtilis", J. Bacteriol., 127 (3), pp. 1502-1518.

[52] T. Fortuna, M. Galkowska, M. Bączkowicz, K. Szkabarska, T. Bartkowska, M. Labanowska and M. Kurzdziel, 2013, "Effect of potassium and magnesium treatment on physicocochanical and rheological properties of potato, corn and spelt starches and on thermal generation of free radicals", Starch/Stärke, 65 (11-12), pp. 912-922.

[53] G. E. Lester and M. A. Grusak, 1999, "Postharvest application of calcium and magnesium to honeydew and netted muskmelons: effects on tissue ion concentrations, quality, and senescence", J. Am. Soc. Hortic. Sci., 124 (5), pp. 545-552.

[54] A. Muschitz, C. Riuo, J. C. Mollet, V. Glaougen and C. Faugeron, 2015, "Modifications of cell wall pectin in tomato cell suspension in response to cadmium and zinc", Acta Physiol. Plant., 37 (11), p. 245.

[55] P. J. Fellows, 2017 "Food Processing Technology, Principle and practice", Food Science, Technology and Nutrition, 4th Edition, London.

[56] S. Dogan, S. Sahin and G. Sumnu, "Effects of batters containing different protein types on the quality of deep-fat-fried chicken nuggets", Eur Food Res Technol, 220, pp. 502–508.

[57] P. Vreka and S. Fiszman, 2011, "Hydrocolloids in fried foods. A review", Food Hydrocolloid, 25, pp. 1801-1812.

[58] K. I. Holownia, M. S. Chinnan, M. C. Erickson and P. Mallikarjunan, 2000 "Quality evaluation of edible film-coated chicken strips and frying oils", J. Food Sci., 65(6), 2000, pp. 1087-1090.

[59] A. R. Norizah, A. R. Junaid, Maryam and A. L. Affah, 2016, " Effects of repeated frying and hydrocolloids on the oil absorption and acceptability of banana (Musa acuminate) fritters", International Food Research Journal, 23 (2), pp. 694-699.

[60] M. Aminlari, R. Ramezani and M. H. Khalili, 2005, "Production of protein-coated low-fat potato chips", Food science and technology international, 11(3), pp.177-181.

[61] A. Suatena, 2009, "Deep frying: Nutrient losses and profits from fried foods", Perspectivas en Nutricion Humana, 10, pp.77-88.
[66] M. Kurek, M. Šćetar and K. Galić, 2017, "Edible coatings minimize fat uptake in deep fat fried products: A review", Food Hydrocolloids, 71, pp. 225-235.

[67] J. Ang, 1989, "The effect of powdered cellulose on oil/fat uptake during the frying of battered food product", Journal of American Oil Chemistry Society, 66, pp. 480–481.

[68] G. Bingol, A. Zhang, ZH. Pan and T. H. Mchugh, 2012, "Producing lower-calorie deep fat fried French fries using infrared dry-blanching as pretreatment", Food Chemistry, 132(2), pp. 686–692.

[69] B. AL-Abdullah, M. Angor, K. AL-Ismail and R. Ajo, 2011, "Reducing fat uptake during deep-frying of minced chicken meat-balls by coating them with some hydrocolloids materials", Ital. J. Food Sci, 23, pp. 331–337.

[70] D. Freitas, S. Berbahi, P. Prati, F. Fakhouri, F. Queiroz and E. Vicente, 2009, "Reducing of fat uptake in cassava product during deep-fat frying", J. Food Eng, 94, pp. 390–394.