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Reducing oil absorption of falafel balls by using edible coating films containing dried orange-albedo powder or dried apple peel during deep frying

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Introduction: The purpose of this study is to examine the effects of varying proportions of dried-orange-albedo and dried-apple-peel powders in edible coating films for falafel balls on their subsequent oil uptake and sensory properties when used during deep frying in oil.

Methods: Coating solutions of 3%, 5%, and 7% w/v of either orange albedo or apple-peel powder were prepared and heated to 90°C for 5 min, after which they were cooled. In the next step, the falafel-ball samples were air-dried after dipping them in the coating solutions. The falafel balls coated with different solutions were then deep-fried and their oil and moisture content with the calculation of oil uptake and moisture retention was analyzed, along with the evaluation of sensory attributes.

Results: According to the results, oil uptake during deep oil frying was reduced to varying extents in all coating treatments. For both orange albedo and apple-peel powder, the coating films containing 5% of either were found to be the most effective level in reducing the oil uptakes.

Discussions: The coating films prepared from orange albedo reduced oil uptake more than those containing the same amount of apple peel for all levels. All falafel ball samples prepared with the different coatings were found to have improved sensory features compared with the uncoated control.

KEYWORDS

apple-peel powder, coating films, falafel balls, oil, orange-albedo powder

1. Introduction

Falafel, a fried ball, comprises spiced fava beans and chickpeas (Abdullah, 2015). It is highly popular in the Middle East and North Africa and is becoming increasingly popular throughout the world, especially in Jordan, where it is considered a favorite food by all social and economic classes (Janakat and Al-Khateeb, 2011). The laborers and low-income families consumed falafel daily either for breakfast, dinner, or as a snack because it is readily available, tasty, and relatively low price. Often, this snack is prepared from chickpeas mixed with parsley, garlic, and special spices, which are deep-fried in vegetable oil (Janakat and Al-Khateeb, 2011).

Frying improves the texture, flavor, and appearance of food after frying; therefore, it is appreciated globally. Moreover, different fried foods like fried chicken, onion rings, French fries, and nuggets are served by global fast-food companies. However, a significant concern with fried food is the high oil content, which can contribute to health issues such as high cholesterol, high blood pressure, and obesity. In addition, frying can generate various oxidation byproducts that have been linked to diseases such as membrane damage,

premature aging, heart disease, and cancer. As a result, consuming fried foods has become a significant health concern (Jerónimo and Alves, 2022). Health organizations and media outlets advocate reducing the proportion of oil in the average diet. One of the main motivations behind current research on reducing the oil content of fried food is the desire to create healthier products with less oil absorbed during the frying process. This has resulted in the creation of various methods to reduce the amount of oil in fried food (Angor, 2016; Ajo, 2017). Several strategies are effective in decreasing the amount of oil absorbed by fried food. One approach to achieve this is to apply an edible film made from an aqueous solution to the food before frying. This coating creates a barrier that prevents moisture loss and reduces the amount of oil absorbed during frying. As a result, the use of coatings is a promising approach for lowering the oil content of fried foods.

The albedo, a white spongy layer of tissue, makes up the majority of citrus peel. It is rich in bioactive compounds such as flavonoids and vitamin C, which have antioxidant properties and can promote good health (Pérez-López and Carbonell-Barrachina, 2005). Orange peels are a common byproduct of the citrus industry and can contribute to environmental pollution if not properly disposed of. However, orange peels are high in carbohydrates, pectin, and fiber, which give them functional properties. As a result, they can be used in various applications (Abou-Arab et al., 2019).

Normally, when apple peel is produced as a byproduct, it is directly disposed of as waste. The peel of apples contains high levels of phenolic compounds, which have anti-oxidant and anti-proliferative properties (Wolfe and Liu, 2003). These compounds, along with dietary fiber, have been shown to have various *in vitro* bioactive effects, such as potentially reducing the risk of coronary heart disease (Massini et al., 2013). There is increasing interest in using natural additives, particularly dietary fibers, as potential antioxidants in various industrial applications, particularly in the fields of cosmetics and food preservation. These fibers are appealing for technological and functional properties, along with their nutritional properties (Pérez-López and Carbonell-Barrachina, 2005). The aim of this study is to assess the effects of using different proportions of orange albedo and apple-peel powder as coating-material films for falafel balls on their oil uptake and sensory properties when used during deep oil frying.

2. Materials and methods

The falafel dough was purchased from the local market. Falafel balls were manually formed using a special ladle, frozen at -18°C for 2 h, and fried as described below.

The coating materials used were apple peel and orange albedo orange powders that were prepared by drying orange albedo and apple peel at $37 \pm 2^{\circ}\text{C}$ in an air oven for 72 h followed by subsequent grinding of the dried peels and sieved to obtain particle sizes of $150 \mu\text{m}$ (Fernández-Ginés et al., 2003).

2.1. Preparing coating-solution

Six solutions of 3, 5, and 7% w/v were made to prepare each coating material (pre-treatments were conducted to choose the

percentage). The solutions were heated for 5 min to 90°C and then cooled at room temperature. Afterward, 3% w/v of glycerol was added to the solutions as a plasticizer. The frozen falafel balls were quickly dipped into the coating solutions for 5 s and then air-dried using a fan. This process was repeated to ensure that the film was evenly coated on the product. Uncoated falafel balls were used as controls.

2.2. Frying

An electrical deep-oil fryer was used to fry the coated and uncoated samples using sunflower oil for 3 min at $180 \pm 5^{\circ}\text{C}$. The temperature and time were controlled using a digital thermocouple. This frying resulted in formation of a golden surface. The oil was replaced for each different coating solution after two batches of frying. Ten falafel balls were placed in the frying basket for each batch, and the basket was immersed in the oil to fry the samples. After frying, the samples were placed on absorbent tissue paper for 10 min to remove excess oil before testing. A portion of the freshly fried samples was used for sensory evaluation immediately, while the remaining samples were stored in plastic bags until needed for chemical and physical analysis. All experiments were performed in triplicate, and the results shown are the average of the obtained results.

2.3. Proximate analysis

After frying, samples were analyzed for moisture and oil content according to AOAC (2000) in triplicate. The oil and moisture data were compared by calculating the percent relative variation in oil uptake (OU%) and moisture retention (MR%) in the coated product compared to the uncoated product, using the following formula stated by Angor (2014):

$$OU = \left[\frac{OU_{\text{coated}}}{OU_{\text{uncoated}}} - 1 \right] \times 100 \quad (1)$$

$$MR = \left[\frac{MC_{\text{coated}}}{MC_{\text{uncoated}}} - 1 \right] \times 100 \quad (2)$$

2.4. Sensory assessment

The sensory quality of the falafel samples was evaluated by a panel of 50 semi-trained individuals selected from the students and staff of the Department of Nutrition and Food Processing at Al-Huson University College. The panel consisted of both male and female participants of various ages who were familiar with falafel products. The samples were randomly coded and individually presented to the panelists for evaluation of sensory attributes (appearance, flavor, color, crispiness, taste, and overall acceptability) for desirability according to the five-point hedonic scale described by Belmes (2018), varying from 5 (like extremely) to 1 (dislike extremely). The taste between testing of samples was

TABLE 1 Oil and moisture contents of different levels of orange-albedo powder as coating films for deep-fried falafel balls.

Treatments	Oil%	Moisture%
0% C	23.96 ^A	40.87 ^D
3%	14.78 ^C	47.60 ^B
5%	11.05 ^D	50.70 ^A
7%	15.10 ^B	45.79 ^C
<i>P</i>	**	**

Values are the average of three replicates, means with different matching letters within the same column are significantly (** $p \leq 0.01$).

TABLE 2 Oil and moisture contents of different levels of apple peel as coating film for deep-fried falafel balls.

Treatments	Oil%	Moisture%
3%	15.17 ^C	45.82 ^B
5%	13.26 ^D	48.62 ^A
7%	19.07 ^B	42.77 ^C
Control	23.96 ^A	40.87 ^D
<i>P</i>	**	**

Values are the average of three replicates, means with different matching letters within the same column are significantly (** $p \leq 0.01$).

neutralized using pieces of bread and water. No information about the sample treatments was given to the panelists, and they were not offered any incentives to participate to avoid bias.

2.5. Data analysis

Data analysis for this study was conducted with the help of Statistical Analysis Software (SAS, 2003). The data obtained were analyzed using a completely randomized design (CRD). A significant difference between data means was estimated using the least significant difference test at p -value < 0.05 .

3. Results and discussion

The oil and moisture content of the falafel balls coated with different levels of dried-orange-albedo powder is shown in Table 1. The data show that for all levels of dried orange albedo used, the oil content was effectively reduced and the moisture-content percentage increased compared with the uncoated sample (C).

The oil and moisture percentage for the deep-fried falafel balls coated with films containing different concentrations of dried orange albedo (3, 5, and 7%) and the control ranged from 11.05–23.96% and 40.87–50.70%, respectively.

All the treatments of albedo orange as coating materials significantly ($p \leq 0.05$) reduced the oil compared with the control. Of all these treatments, the lowest oil percentage (11.05%) was obtained for the coating film with 5% albedo orange. This result is in agreement with those of Lazaridou and Biliaderis (2020), who, using polysaccharide as a coating formulation, reported that French fries coated with a mixture of CMC (0.5% w/w) and pectin (1%

w/w) had lower oil uptake compared to the uncoated sample. In addition, Angor (2014) concluded that using a 5% solution of whey protein isolate as a coating for foods like potato-pellet chips may reduce oil absorption during deep frying. This may be due to the formation of covalent bonds within the film during heating, which can lead to decreased oil absorption.

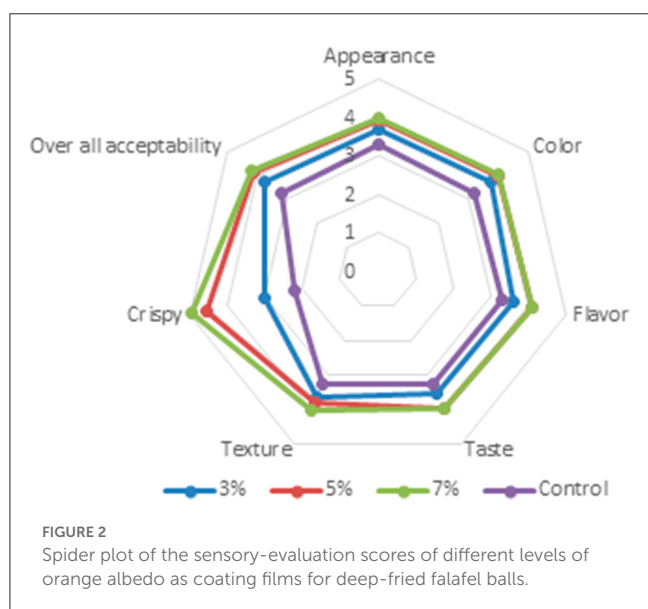
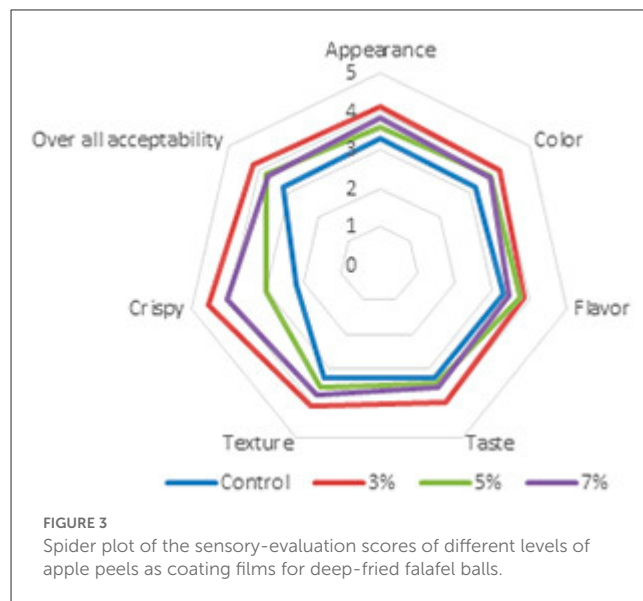
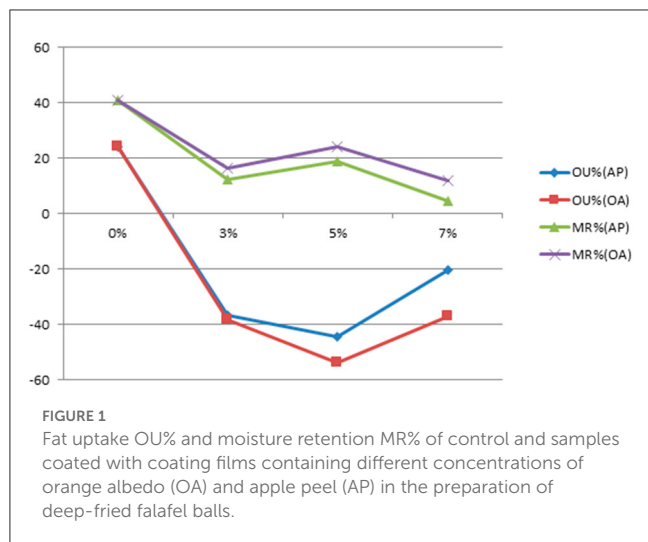
The results presented in Table 2 show the oil and moisture content of falafel balls coated with films containing different levels of apple peel. The data demonstrate that using any amount of apple peel as a coating was effective at increasing the moisture content and decreasing the oil content in comparison to the control sample (C).

The oil and moisture percentage in the deep-fried falafel coated with films containing different concentrations of apple peel (3, 5, and 7%) and the control ranged from 13.26–23.96% and 40.87–48.62%, respectively. All the treatments of apple peel as coating materials significantly ($p \leq 0.01$) reduced the oil percentage compared with the control. Of all these treatments, the lowest oil percentage (13.26%) was obtained for the coating film with 5% apple peel. Al-Asmar et al. (2019) illustrated that the use of a pectin-based solution resulted in a reduction of the oil content of treated falafel balls to about 23%.

There was an increase in the moisture content of fried falafel balls coated with different concentrations of apple peel with their increasing concentration in the coating. The 5% apple-peel coating resulted in fried falafel balls with the increased level of moisture content. This result is in agreement with those of Al-Asmar et al. (2019), who found that falafel balls treated with a 1% pectin-based solution had significantly increased water content compared with the control. Many researchers have obtained similar results, including Garmakhany et al. (2014) and Mahajan et al. (2014). In addition, Angor (2014) concluded that the use of whey protein or its isolate as a coating on potato-pellet chips can increase the moisture content up to 48.62% compared to uncoated controls. The coating creates a barrier that helps to retain moisture during frying, which may be the reason for the increase in moisture content.

Figure 1 shows the oil-uptake and moisture-retention percentages associated with different levels of orange-albedo powder and apple peel in films used for coating falafel balls during deep frying. The oil uptake is lower in coated samples compared to uncoated samples (c) because the coating reduces the oil content. In this work, the highest oil uptake observed for the orange albedo is (-53.86 ± 0.32), and for the apple peel, it is (-44.65 ± 1.397). These results are in agreement with those of Jafarin and Mohammadnejad (2020) and Liu et al. (2021), who concluded that the use of gum coating reduces the oil absorption of fried products. When using either orange albedo or apple peel in coating films, the most effective reduction in oil uptake of falafel balls was at a level of 5% in both cases.

The impact of different treatments of orange albedo and apple peel as coating films on the reduction in oil absorption led to increased retention of moisture in the deep-fried falafel balls. Coated samples had higher moisture content than uncoated samples (controls), resulting in positive moisture retention for each coating film made of orange albedo or apple peel. This trend continued until the concentration reached 5%. Angor (2016) found that the formation of a protective film on the surface of samples during the early stages of frying due to thermal



(control). Figure 3 has shown the scores for the appearance and color of the samples coated with orange albedo ranging from 3.68–3.96 and 3.76–4.04, respectively, corresponding to the range of like to like very much. This may have been because most people enjoy falafel balls in different ranges of color. No significant differences was observed between the treatments, and the scores for these treatments were higher than the control.

The other attribute scores, crispiness, taste, and flavor of the samples coated with orange albedo were in the ranges of 3.6–4.12, 3.52–3.96, and 3.64–4.00, respectively (Figure 2). The figure represents the mean sensory profile based on the 5-point rating scale, where 5 refers to like extremely and 1 refers to dislike extremely. There were no significant differences ($p \leq 0.05$) between the treatments, and the scores for these treatments were higher than those of the control. Mohamed and Mohamed (2018) reported that coating treatments improved the sensory attributes of potato chips compared with uncoated treatments.

The overall acceptability scores for samples coated with orange albedo ranged from “like” to “like very much” (as shown in Figure 2), while the uncoated sample had a lower overall acceptability score compared to all the coated treatments. However, the differences in overall acceptability between the various treatments of falafel balls were minor. These results are in agreement with those of Angor (2016) and Ajo (2017), who found that edible coating films can improve the sensory attributes of French fries compared to uncoated samples. The highest scores for all sensory attributes were achieved using a 5% concentration of orange albedo as a coating film.

Figure 3 represents the mean sensory profile based on the 5-point rating scale, where 5 refers to like extremely and 1 refers to dislike extremely. The overall acceptability scores for samples coated with apple peel ranged from “like” to “like very much” (as shown in Figure 3). The lowest overall acceptability score was determined for uncoated sample, unlike all the coated treatments. However, there were minor differences in overall acceptability between the different treatments of falafel balls. These results conform to those of Tak and Jain (2019), who found that uncoated

gelation led to a reduction in oil uptake and an increase in moisture retention.

Oil absorption is determined by the food’s moisture content because the vapor generated during heating leaves voids into which oil can subsequently enter (Oke et al., 2018). However, the orange-albedo and apple-peel films form a layer of gel, which reduces the penetration of oil and, thus, the evaporation of water. The orange-albedo-coating films reduced oil uptake to a greater extent than the apple peel for all corresponding treatments. Angor (2016) reported the effectiveness of pectin in reducing oil content when used as a component of coatings.

The material’s sensory characteristics being marketed attract the consumers. The control (uncoated) and deep-fried falafel balls’ overall acceptability prepared using orange-albedo and apple-peel coating films were determined according to a five-point hedonic scale for appearance, color, crispiness, taste, texture, and flavor with results shown in Figures 2, 3, respectively.

All coating treatments (orange albedo and apple peel) improved all sensory-attributes scores compared with the uncoated treatment

and coated samples were almost equally acceptable based on sensory-scores since no significant difference was noted between the control and treatment samples. In our study, the sensory characteristics of deep-fried falafel balls that had been coated with apple-peel film treatments (Figure 3) had nearly the same trend as those coated with orange-albedo films.

4. Conclusions

Coating falafel balls with dried orange albedo or apple-peel powder in various concentrations can reduce oil absorption while deep frying. The most effective level of reduction in oil uptake was -53.86% for the orange albedo and -44.65% for apple peel when included at a level of 5% in films in both cases. The orange-albedo coating films reduced the oil uptake to a greater extent than the apple peel when comparing the same amount for all levels. It is important to evaluate the sensory qualities of food products. In this study, coating falafel balls with dried orange albedo or apple-peel powder improved all sensory features compared to the uncoated control.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

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