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EXPLORING THE IMPACT OF FOOD CONTACT DURATION ON CARDBOARD CONTAINING PERFLUORINATED COMPOUNDS IN LOCAL MARKETS OF BAGHDAD GOVERNORATE

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ABSTRACT

In this experimental study, various tests were conducted on the thickness, imbibition, roughness, and microstructure of cardboard containing perfluorinated compounds for some boxes of crispy chicken, french fries, and ice cream commonly used in Baghdad Governorate, to study the effect of crispy chicken and french fries for a period of time (10, 20, 30) minutes and ice cream. (15,30,45) days on some of its properties, and the results revealed that the thickness and percentage of imbibition increased directly with increasing experiment duration at all temperatures studied. The lowest values were reported in 10 minutes for boxes of crispy chicken, French fries boxes, and 15 days for ice cream boxes. The thickness was (326,637.333, 270.333) µm, and the percentage of imbibition was (247,15,294)%, respectively. The longest time taken was 30 minutes for crispy chicken boxes and French fries boxes, and 45 days for ice cream boxes. The thickness was calculated to be (334, 644.333, 283.167) µm, and the percentage of imbibition was (331, 205, 423)%. At all temperatures utilized in the investigation, the roughness and microstructure assessment values increased directly with the duration of the migration experiment. The lowest roughness values were recorded at 10 minutes for the crispy chicken box and French fries boxes, and 15 days for the ice cream box (0.431, 0.167, and 0.501), respectively, whereas the highest values were recorded at 30 minutes for the crispy chicken box and potato box, and 45 days for the ice cream box (0.522, 0.264, 0.806). The lowest microstructure values (0.103, 0.037, 0.115) micrometers were obtained after 10 minutes for crispy chicken boxes and French fries boxes, and 15 days for ice cream containers. The highest values (1.443, 0.047, 0.313) µm were measured after 30 minutes for crispy chicken boxes and French fries boxes, and 45 days for ice cream boxes.

Keywords: cardboard, thickness, imbibition, roughness,microstructure.

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استكشاف تأثير مدة ملامسة الغذاء على الورق المقوى المحتوي على مركبات بيرفلورية في الأسواق المحلية لمحافظة بغداد

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الخلاصة

أجريت فحوصات السمك، التشرب، الخشونة، البنية المجهرية للورق المقوى المحتوي على مركبات بيرفلورية لبعض علب الدجاج المقرمش، البطاطا المقلية، المثلجات شائعة الاستخدام في محافظة بغداد، لدراسة تأثير الأغذية من الدجاج المقرمش والبطاطا المقلية لمدة زمنية (10, 20 ,30) دقيقة والمثلجات (15 ,30 ,45) يوم على بعض خواصها، وأظهرت نتائج قيم السمك والنسبة المئوية للتشرب بها تزدادِ طردياً مع زيادة مدة التجربة إذ سُجلت أقل القيم في الوقت الذي استغرق 10 دقائق لعلب الدجاج المقرمش و علب البطاطا المقلية و15 يوم لعلب المثلجات. وقد بلغت قيم السمك (270.333 ، 32.637) ميكرومتر على التوالي، والنسبة المئوية للتشرب (249 ,15 ,247)% على التوالي، وتم تسجيل أعلى القيم في الزمن المستغرق 30 دقيقة لعلب الدجاج المقرمش وعلب البطاطا و45 يوم لعلب المثلجات وقدرت قيمة السمك (270.333 ,334 ,644) ميكرومتر على التوالي والنسبة المئوية للتشرب (423 ,205 ,331) %على التوالي. لوحظ ازدياد قيم فحص الخشونة والبنية المجهرية بشكل طردي مع زيادة مدة التجربة في جميع درجات الحرارة المستخدمة في الدراسة، أذ سجلت قيم الخشونة أقل قيم عند وقت 10 دقائق لعب الدجاج المقرمش و علب البطاطا المقلية و15 يوم لعلب المثلجات (0.431, 0.167, 0.501) ميكرومتر على التوالي، وسجلت أعلى القيم عند وقت 30 دقيقة لعلب الدجاج المقرمش و علب البطاطا المقلية و45 يوم لعلب المثلجات (0.522, 0.264, 0.806) ميكرومتر على التوالي. وبلغت أقل قيم للبنية المجهرية عند وقت 10 دقائق لعلب الدجاج المقرمش و علب البطاطا المقلية و15 يوم لعلب المثلجات (0.103, 0.037 , 0.115) ميكرومتر على التوالي وسجلت أعلى قيم عند وقت 30 دقيقة لعلب الدجاج المقرمش و علب البطاطا المقلية و45 يوم لعلب المثلجات (1.443, 0.047, 0.313) ميكرومتر على التوالي.

الكلمات المفتاحية: الورق المقوى, السمك, التشرب, الخشونة, البنية المجهرية.

INTRODUCTION

Packaging is an integral part of our daily lives, often overlooked in terms of its quality and significance. Its meticulous design is intended to deliver food in an appealing, secure, and convenient manner (FAO, 2012). Beyond this practical aspect, packaging plays a crucial role in shaping the social and economic dynamics of society, influencing food choices, consumption patterns, and family engagement **(Sürücüoğlu & Çakıroğlu, 2000)**. The changing landscape of meal preparation time in the kitchen, along with a decline in home-cooked meals and consumer well-being, has fueled a growing demand for ready-to-eat foods and desserts **(Tudoran *et al*., 2012)**. This shift aims to reduce the time and effort expended in preparing and consuming food, so ready-to-eat foods are considered. The answer to these issues and needs **(Buckley *et al.,* 2007)**.

To protect food quality, cardboard includes inherent or chemical components in its composition that inhibit the permeability of fat penetration **(Ali *et al*., 2015)**. Perfluorinated materials have been utilized to improve the oil and water-resistant qualities of paper and cardboard since their discovery in 1938 **(Teflon, 2021)**. Some perfluorinated compounds have been applied to packaging cardboard since the 1950s. These applications are mostly aimed at fatty meals, particularly those in which the food is placed while hot or held for an extended time, such as the support of fast-food boxes containing French fries and hamburgers **(Susmann *et al.,* 2019)**. These resistance characteristics are critical. Oils, grease, and water may be transferred from food during baking, transit, and storage, or for use with fast food, particularly in the food packaging business. As a result, these materials come into touch with the meal **(.Buck *et al*., 2011)**. However, no compounds in contact with food are fully inert, therefore it is probable that Because meals and beverages can interact strongly with the things they touch, their chemical components migrate in small amounts when they come into contact with specific types of foods. Fats and oils, for example, promote the dissolution or transfer of plastic components from packaging to food, and plant products remove copper ions **(Al-Hayani *et al.*, 2022).**

The use of chemical compounds may lead to environmental risks **(Khaleel *et al.*, 2019; Sura *et all* , 2022)**, so it is preferable to use environmentally friendly ingredients when manufacturing **(Chalob & Abdul-rahman, 2018)** , and as consumers need to increase awareness about food safety and develop knowledge about it **(Alsoufi, 2022)**, most consumers do not distinguish between transmitted diseases through food **(Alkhafaji, 2023)**, their attention is focused on the quality of food and its good packaging **(Alsoufi,2021)**. Therefore, quality specifications must be applied, and limits must be set for materials entering the market **(Husain & alkhafaji, 2022).**

Due to the importance of packaging for its use in protecting foodstuffs from environmental pollution and other influences, which is essential to ensuring food safety while also extending shelf life and reducing food waste **(Narayanan *et al.* 2017; Ribeiro-Santos *et al.*, 2017*)***, in- depth studies on food packaging have been conducted due to the increasing consumer demand for high-quality foodproducts **(fraji *et al.*, 2016).**

According to a previous literature survey, conducted a study on the imbibition and evaporation of water droplets on paper media commonly employed in inkjet printing, utilizing a high-speed imaging system. Their research revealed that, for 60 µL water droplets, glossy coated paper exhibited a total imbibition and evaporation drying time of 10-15 ms, while matte coated paper displayed a range of 30-150 ms. Notably, the impact of evaporation on multi-purpose paperdrying was observed, indicating an initial drying rate in the range of 0.4–0.6 pL/s **(Oko & Swerin, 2011)**. On the other hand, **Marin (2021)**, examined 15 sheets of cardboard under consistent relative humidity levels to explore the relationship between cardboard's mechanical properties and atmospheric humidity. The study revealed a reduction in mechanical properties with increasing humidity, consequently diminishing the overall performance of the packaging material. The current investigation aims to assess the impact of the duration of food contact with cardboard- based fast food packaging containing perfluorinated materials. The study will focus on specific physical properties influencing the final quality of the packaging and will also consider the chemical composition of the intended food products.

MATERIALS AND METHODS

Preparation of samples

Samples were collected from cardboard in Baghdad Governorate in 2022, with a special focus on a crispy chicken box, a French fries box, and an ice cream box. The food products were carefully prepared to be compatible with the indicated packing materials. The study design included three unique time treatments (10, 20, and 30 minutes), each accompanied by a temperature treatment specific to the food item in question. The crispy chicken was treated at temperatures of (37-60, 32-60, 30-60)°C, the fried potatoes at (37.5-65, 36-65, 33.5-65)°C, while the ice cream containers were kept at (-18)°C for (15, 30, 45) days. Until the moment of testing, each sample was separately packed in a bag. It is crucial to highlight that the results of this study may not offer a complete picture of the packaging available in local markets.

Chemical analysis of food

The protein, moisture, fat, ash, and fiber contents of foods were quantified utilizing the methodology outlined in A.O.A.C **(A.O.A.C, 2005).** Carbohydrates were determined using Pearson's difference between components approach **(Pearson, 1976)**.

Physical analyzes of paperboard

Thickness measurement for paperboard

The thickness of the cardboard was determined using an Australian-made Digital Micrometer device (IDM, type D0007) available in the quality control laboratory at the National Packaging Center. The measurement followed the guidelines outlined in the device's operating manual within the laboratory.

Determination of imbibition quantity for paperboard

The imbibition of the cardboard was assessed using an Australian-made Cobb Moisture Absorption Tester (IDM, type C0006&C0005) located in the quality control laboratory at the National Packaging Center. The procedure adhered to the instructions provided in the laboratory manual.

Roughness determination

Cardboard roughness was evaluated utilizing a roughness estimation device from the Swiss company Mettler, housed in the Materials Engineering Laboratory at the University of Technology. The assessment followed the guidelines outlined in the operating manual of the device.

Microstructural analysis

Microstructural analysis of the cardboard samples was conducted using a FESEM Field Emission Scanning Electron Microscopy device (type F50, model INSPECT, USA). Before analysis, all samples underwent gold coating using a spray coating device (CY-PSP180G-1TA).

RESULTS AND DISCUSSION

Chemical analysis of food

Table 1 presents the results of the chemical analysis conducted on the experimental food materials. The crispy chicken sample exhibited the following percentages for carbohydrates, crude fiber, protein, fat, ash, and moisture: (9.31, 8.46, 21.87, 14.84, 1.80, and 43.72) %, respectively. Meanwhile, the fried potato sample revealed values of (13.41, 5.58, 10.93, 21.00, 1.59, and 47.49) % for carbohydrates, crude fiber, protein, fat, ash, and moisture, respectively. The chemical analysis of the ice cream sample indicated percentages of (0.17, 0.19, 4.37, 13.95, 0.52, and 80.80) % for carbohydrates, crude fiber, protein, fat, ash, and moisture, respectively.

Table (1): Results of chemical analysis of food based on wet weight.

sample	Carb. %	Fibers %	Protein %	Fat %	Ash %	Moisture %
Crispy chicken	9.31	8.46	21.87	14.84	1.80	43.72
Fried Potatoes	13.41	5.58	10.93	21.00	1.59	47.49
Ice cream	0.17	0.19	4.37	13.95	0.52	80.80

Thickness of cardboard

The thickness values of the cardboard samples are shown in Table 2, as well as their fluctuation throughout different treatment periods. The lowest recorded value for crispy chicken boxes and French fries boxes subjected to food treatment was seen during 10 minutes, measuring (326,637.333)µm, respectively. The greatest readings for both crispy chicken boxes and French fries boxes occurred at 30 minutes, with values of (334,644.333)µm. In the case of ice cream boxes, the highest thickness reading was 283.167 µm after 45 days of storage, while the minimum thickness reading was 270.333µm after 15 days of storage.

TABLE (2): Thickness values of cardboard in contact with food.

sample of can	treatment	Thickness µm
Crispy chicken	Control sample	347.833
	min 10	326
	min 20	330.667
	min 30	334
Fried Potatoes	Control sample	661.333
	min 10	637.333
	min 20	642.167
	min 30	644.333
Ice cream	Control sample	257.5
	day 15	270.333
	day 30	281.667
	day 45	283.167

From the above it appears that crispy chicken boxes and potato boxes have lower thickness values when treated for 10 minutes than the thickness values of the control sample and then increase directly with increasing duration of treatment with food. The decrease at the start of treatment may be attributed to the effect of food temperature (60-65)°C, respectively, with hot steam on the cans, which reduces their thickness, then they rise again due to increased food interference and absorption of moisture and fat, as the crispy chicken and fried potatoes contained moisture and fat percentages of (43.72, 47.49, and 14.84, 21.00)

%,respectively, while The results of the values of the ice cream cans showed that, although they recorded the lowest values when treated for 15 days, they were higher than the values of the thickness of the control sample, while continuing to rise directly with the increase in the duration of the experiment. This increase may be attributed to the sample of the ice cream cans, as long-term storage encourages the cans to absorb the ingredients of ice cream, especially moisture, as it contains a high percentage of moisture estimated at 80.80 % and fat 13.95 %, this may encourage the migration of chemical compounds such as perfluorinated substances from the packages to the food. Thickness is an important property of cardboard because it affects the quality of the final product when used, and the thickness of the paper varies depending on the manufacturers and purpose of manufacturing.

Imbibition of cardboard

(Table, 3) presents the percentage of absorption for the cardboard samples and its correlation with the period. Observing the results for crispy chicken boxes and French fries boxes, a distinct reduction in values is evident at 10 minutes, registering (247, 15) %, respectively. Contrastingly, higher values emerge at the 30 minutes, reaching (331, 205) %, respectively. Notably, the ice cream container exhibited the highest absorption percentages after 45 days of storage, reaching 423%, while the lowest values were recorded after 15 days of storage, measuring 249%.

TABLE (3): Percentage of imbibition of cardboard in contact with food

sample of can	treatment	Imbibition %
Crispy chicken	Control sample	344
	min 10	247
	min 20	265
	min 30	331
Fried Potatoes	Control sample	144
	min 10	15
	min 20	55
	min 30	205
Ice cream	Control sample	389
	day 15	294
	day 30	404
	day 45	423

The above findings demonstrate a consistent direct increase in the observed values with a prolonged duration of the experiment. Despite an initial decrease in values noted at the 10-minute treatment for crispy chicken boxes and potato boxes, as well as at the 15-day storage period for ice cream cans, in comparison to the control samples, there is a subsequent rise in values as the exposure time extends. This pattern suggests a potential alteration in the crystallization or pore size distribution of the cans due to the influence of humidity. Given the elevated moisture levels in foods, especially in ice cream as indicated in Table I, over time, there is an increased likelihood of material penetration into the pores, impacting mechanical properties. Consequently, this raises the possibility of chemical compounds migrating into the food. It is essential to note that imbibition properties exhibit variability depending on the type of cardboard and manufacturing parameters.

Roughness of cardboard

Table 4 illustrates the roughness values of the cardboard samples and their correlation with the treatment period. Examining the results for crispy chicken boxes and French fries boxes reveals that the lowest value at the 10-minute treatment time is (0.431, and 0.167) µm, respectively. Conversely, the highest values are observed at the 30-minute treatment time, measuring (0.522, and 0.264) µm, respectively. Similarly, for ice cream containers, the lowest roughness value after 15 days of storage is 0.501 µm, while the highest value after 45 days of storage is 0.806 µm. µm.

Based on the findings, there seems to be a clear correlation between roughness values and treatment time in samples of crispy chicken and French fries boxes. Longer duration correspond to higher roughness values. Despite a decrease in values after a 10-minute treatment compared to the control sample, they subsequently increased again. This initial decline could be attributed to the influence of heat and steam. As the food comes into contact with the container and its temperature drops (30 to 33.5) °C, interacting with the sample containers,it leads to a subsequent rise in roughness values.

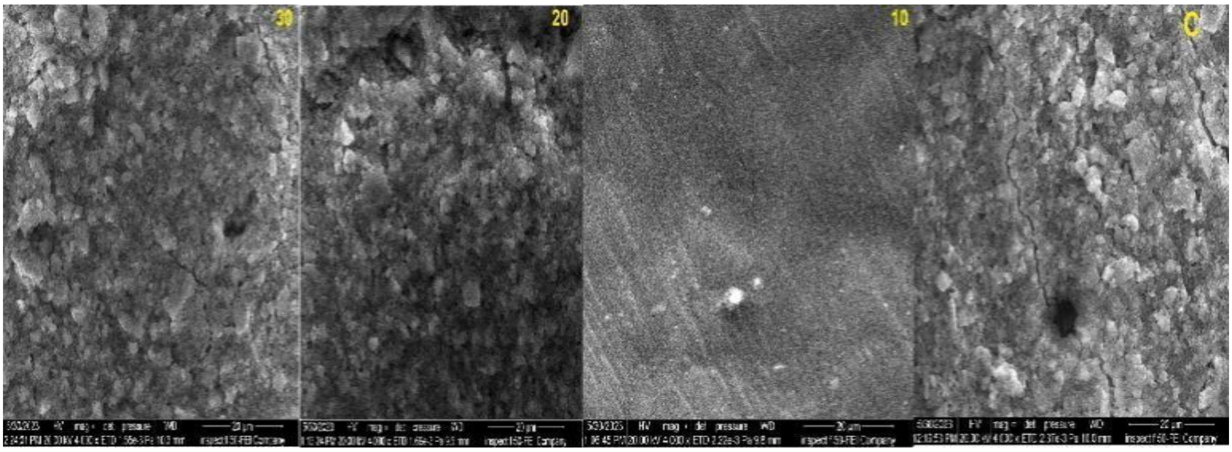

Figure (2): Microstructure of French fries box with the effect of time (control sample C (10-20-30) minutes from right to left).

TABLE (5): Microstructure of cardboard in contact with food

sample of can	treatment	Microstructure µm
Crispy chicken	Control sample	0.274
	min 10	0.103
	min 20	0.816
	min 30	1.443
Fried Potatoes	Control sample	0.039
	min 10	0.037
	min 20	0.042
	min 30	0.047
Ice cream	Control sample	0.055
	day 15	0.115
	day 30	0.180
	day 45	0.313

According to the observations, the ice cream containers had the lowest value after 15 days of storage (0.115 µm) and the highest value after 45 days of storage (0.313 µm). As seen in Fig. 3, there is a considerable change in surface particle size when compared to the control sample, with a steady rise noted during the storage period.

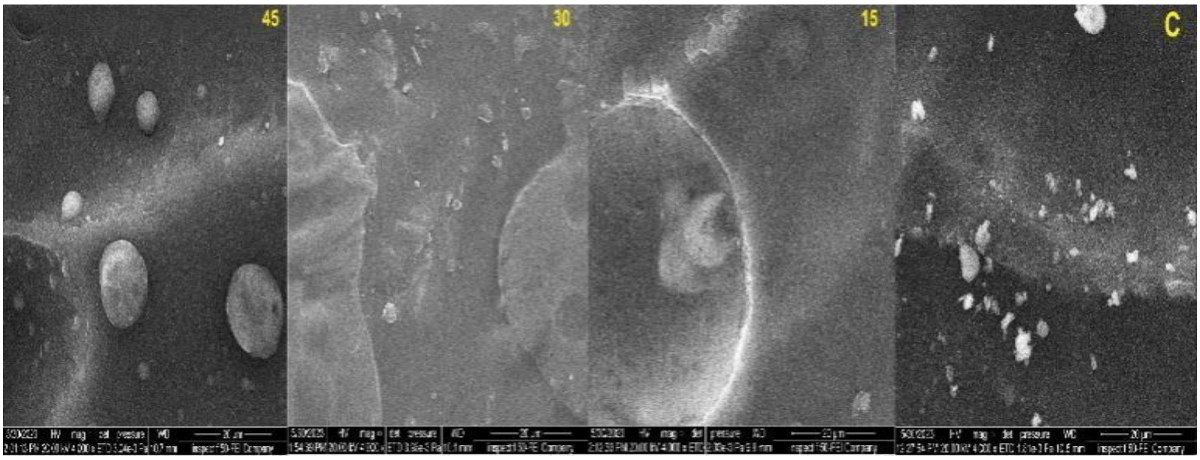

Figure (3): Microstructure of ice cream container with the effect of time (control sample C (15-30-45) day from right to left).

The presented findings indicate a direct correlation between microscopic structure and the duration of treatment for both crispy chicken and French fries cans, with the highest values consistently observed at the 30-minute mark. This trend extends to ice cream cans, where the peak reading occurs after 45 days of storage. The pore size of treated cans undergoes modifications compared to the control sample, influenced by the interference and friction of food with the cans, along with the impact of heat treatment. This results in an observable increase in the microstructure values across the examined samples. Consequently, there is an elevated risk of perfluorinated material migration due to the expanded surface area exposed to them. It is noteworthy that changes in microstructure directly impact the quality and visual appearance of the cans during used.

CONCLUSIONS

The findings highlight a direct correlation among thickness values, impregnation percentage, roughness, and microstructural changes in cardboard containing perfluorinated compounds. This relationship becomes more pronounced with prolonged contact durations between the cardboard and food, especially when accompanied by increased percentages of moisture and fat in the food. These interconnected factors collectively exert influence on the physical and aesthetic properties of the cardboard containers, as evident from microstructure images. This interplay is crucial as it directly affects shelf life and the cardboard boxes' ability to preserve food until consumption. Therefore, it is imperative to design and manufacture cardboard boxes in a way that aligns with the chemical composition of the intended food products, meeting both safety and consumer preference criteria.

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