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# Effect of Some Packing Materials on Oxidative Stability of Fats in Date Biscuits

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## ABSTRACT

Functional biscuits are considered energetic dietary supplements for children suffering from malnutrition and micronutrient deficiency. Biscuits stuffed with date paste and fortified with minerals and vitamins have a considerable fat content where lipid oxidation processes may occur with improper packing which affects the quality and safety of biscuits leading to their contamination with pathogenic microorganisms and toxic chemicals. Therefore, the current study aimed to investigate the oxidative stability of fats in date biscuits and their shelf life under different types of packing materials ranging from sealed translucent polypropylene (PP), and sealed metalized polypropylene (MPP), compared with the control unsealed translucent polyethylene (PE) bags. Physicochemical, microbiological, storage and sensory evaluations for biscuits samples under the different packing materials along with the chemical migration test for the packing materials were carried out. Results showed significant differences ($P < 0.05$) among samples with increasing acidity, peroxide value, diene, and triene, whereas, the iodine value and oxidative stability decreased with storage periods. Fatty acid composition showed slight changes with a decrease in unsaturated fatty acids (ΣUSFA) due to the lipid oxidation processes with the emergence of *trans*-fatty acids after 90 days of storage with the emergence of microbiological activity expressed in a considerable increase in the aerobic plate count (APC) and total combined yeasts and molds count (TYMC) in the control sample (PE) compared with PP and MPP with the superiority of MPP as the best packing material for maintaining the best quality and safety of biscuits with lowest lipid oxidation and highest shelf life.

## 1. Introduction

Biscuits are flour-based baked products that are increasingly consumed worldwide due to their cost-effectivity and being ready to eat in nature. Biscuits fortified with minerals and vitamins are considered as high energy food that has many beneficial impacts on the economy by reducing healthcare costs related to malnutrition, efficiently supporting the national food systems, and ensuring families' food security linked to enhanced cognitive, academic, and psychosocial development stimulating the community by transferring nutritional culture endorsing children's and their families lifelong healthy eating habits. (Rakshit & Srivastav, 2022). Biscuits are common fast foods mainly high in carbohydrates, fat, and calories but low in protein, fiber, vitamins, and minerals. Functional biscuits enriched with minerals and vitamins were developed for malnourished school children as a supplementary food with an effective content of iron as iron deficiency adversely affects the physical growth of school-aged children. Date paste extracted from the date fruit contains valuable nutrients, is a good source of dietary fiber, antioxidants, carotenoids, and phenolics, and is utilized also as a sugar

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substitute and filler in biscuits stuffed with date paste as an excellent functional food for energy malnourished children and adults (Agu et al., 2020).

Fats are the main ingredients in biscuits formulations, having a major role in both dough and final product and providing the desired organoleptic acceptability with energy. The polyunsaturated fatty acids found in shortening used in the processing of biscuits are susceptible to lipid oxidation which is a major factor in reducing shelf life, nutritional value, and products' quality and safety. Lipid oxidation is a health risk process that reduces the nutritional benefits, quality, and safety. The unsaturated fatty acids found in the fats fraction in biscuits are more susceptible to oxidation due to the high baking temperatures with some bad storage conditions such as exposure to heat, light, moisture, and metal ions, thus promoting the formation of free radicals which furthermore react with oxygen resulting in the formation of hydroperoxides which undergone further breakdown into ketones, alcohols, aldehydes causing off-flavors with increased health risk of the chronic non-communicable diseases (NCDs) (Kouhsari et al., 2022). Monitoring changes during product circulation and storage is essential for the overall assessment of quality and safety. Acidity, peroxide value (PV), oxidative stability, fatty acid composition, and *trans*-fatty acids, diene, and triene, are the most important criteria characterizing the quality of biscuits related to the composition of their lipid fraction (Almoselhy et al., 2021).

The functions of biscuit packaging are as follows: (1) Present the biscuits in an attractive way for potential consumers. (2) Show the type, weight, ingredients, and manufacturer of biscuits. (3) Maintain biscuit freshness and flavor over long shelf life. (4) Provide an effective barrier for moisture and foreign odor. (5) Resist seepage of fats and oils. (6) Protect from the harmful effects of visible and UV light. (7) Guarantee the secure transportation of biscuits without damage. (8) Stack well on supermarket shelves (Davidson, 2019). Food packaging retards deterioration, extends shelf life, increases food quality and safety, and combats 3 major external factors: chemical, biological, and physical. Different packing materials have different effects on lipid oxidation, therefore, a careful selection of packing material is necessary. The migration of contaminants and additives from plastic packaging materials to food has been frequently recorded with increasingly emerging safety concerns and health risks (Pack et al., 2021).

Therefore, the current study aimed to investigate the lipid oxidation and shelf life of date biscuits under different types of packing materials such as sealed translucent polypropylene (PP) or plastic, sealed metalized polypropylene (MPP), and unsealed translucent polyethylene (PE) bags as control samples. Physicochemical analysis (refractive index, acidity, peroxide value, iodine value, oxidative stability index, diene, and triene), fatty acid composition, along with the most important chemical migration testing of packing materials, microbiological analysis (aerobic plate count, total combined yeasts and molds count, pathogenic bacteria, aflatoxins B1, B2, G1, G2 and deoxynivalenol), pesticides, sensory evaluation, with the effect of storage on the quality parameters, were carried out, to reach the best packing material with the highest safety and superior protection of biscuits against lipid oxidation and deterioration which shorten the shelf life and poses health risks upon children.

## 2. Materials and methods

## Materials

### Raw materials

All ingredients; plain flour, shortening, date paste, sugar, vanilla, sodium bicarbonate, common salt, Vitamix, and milk powder were purchased from a certified company registered in the White List of the National Food Safety Authority (NFSA), Egypt.

### Chemicals and reagents

All solvents and chemicals used in the study were of analytical and HPLC grade.

### Formulation and manufacturing of date biscuits

School meal biscuits stuffed with date paste were formulated, manufactured, and packaged according to the Egyptian Standards (Egyptian Standards, 2008) for biscuit for schools in accordance with recommendations of the National Nutrition Institute (NNI), Ministry of Health (MOH), Egypt. Three batches were packed in three different packing materials; the sealed transluscent polypropylene (PP) or plastic, the sealed metallized polypropylene (MPP) and the unsealed transluscent polyethylene (PE) bags as control samples. All samples were stored in a cool dry place away from direct sunlight till analysis and sensory evaluation, where samples were taken at 0, 30, 60, and 90 days.

## Analytical Methods

### Physicochemical quality parameters of date biscuits under different types of packing materials

Date biscuits under different packing materials were evaluated for physicochemical quality parameters, oxidative stability, and fatty acid composition.

Refractive index (RI), and peroxide value (PV) were determined according to the method described in AOAC Official Method 965.33 (AOAC, 2016). Acidity was determined according to the method described in ISO 660:2020 (2020). The fatty acid composition was determined according to the method described in ISO 12966-2:2017 (2017c) and the iodine value was calculated from the fatty acid composition (Kyriakidis & Katsiloulis, 2000). Oxidative stability was determined by the Rancimat method according to the method described by Gutiérrez (1989). Ultraviolet (UV) spectrophotometry was determined for the primary oxidation products (conjugated diene) measured at 232 nm and the secondary oxidation products (conjugated triene) measured at 270 nm according to the method described in ISO 3656:2011 (2011).

### Chemical migration testing of packing materials

Chemical migration testing of packing materials was carried out according to the method described by (Zhang et al., 2022) for the sealed translucent polypropylene (PP), the sealed metalized polypropylene (MPP), and the control unsealed translucent polyethylene (PE) bags by soaking the packing materials in 10% ethyl alcohol and 3% acetic acid for 20 days at room temperature, then the determination of copper, zinc, manganese, iron, cobalt, and lithium using inductively coupled plasma mass spectrometry (ICP-MS) and determination of barium using inductively coupled plasma optical emission spectrometry (ICP-OES) was carried out in solution according to the method described by (Sepe et al., 2003).

### Microbiological analysis of date biscuits under different types of packing materials

Microbiological analysis was carried out for date biscuits under different types of packing for different storage periods (0, 30, 60, and 90 days) according to the method described in ISO 4833-1:2013 (2013) for aerobic plate count (APC) with total combined yeasts and molds count (TYMC), ISO 7932: 2004 (2004) for *Bacillus cereus*, ISO 16649-2: 2001 (2001) for *Escherichia coli*, ISO 6579-1:2017 (2017a) for *Salmonella*, and ISO 11290-1:2017 (2017b) for *Listeria species.*

### Determination of aflatoxins and deoxynivalenol in date biscuits under different types of packing

Analysis of aflatoxins (B1, B2, G1, G2) and deoxynivalenol in date biscuits was carried out according to the method described by (Sulyok et al., 2020) using liquid chromatography-tandem mass spectrometry (LC-MS/MS).

### Determination of pesticides in date biscuits under different types of packing materials

Pesticides were determined in date biscuits according to the method described in the European Standard (European Standard Method, 2018) using LC-MS/MS.

### Sensory evaluation of date biscuits under different types of packing materials

Sensory evaluation of date biscuits under different types of packing was carried out after 30 days of storage, through 10 panellists using a 9-point Hedonic scale according to the method described by (Azab et al., 2022).

## Sensory evaluation of date biscuits under different types of packing materials

Sensory evaluation of date biscuits under different types of packing was carried out after 30 days of storage, through 10 panellists using a 9-point Hedonic scale according to the method described by (Azab et al., 2022).

## Statistical Analysis

Physicochemical quality parameters were carried out in triplicates, whereas, sensory evaluation was in ten replicates. Data were presented as means with LSD, tested by T-test and analysis of one-way variance (ANOVA) at $P < 0.05$ using SPSS software (SPSS, 2008).

# 3. Results and discussion

## Physicochemical quality parameters of date biscuits under different types of packing materials

Physicochemical quality parameters and the effect of storage on date biscuits under different types of packing are shown in Table 1.

From the results summarized in Table 1., significant differences ($P < 0.05$) existed among the three used packing materials; polyethylene (PE), polypropylene (PP), and metalized polypropylene (MPP) which reflect the effect of different backing materials on the physicochemical quality parameters. Acidity increased with storage time among all packing materials with minimum values for MPP followed by PP, then PE packing. PV increased with the same trend as in acidity, but the change was more obvious with minimum values for MPP followed by PP, then PE packing. Iodine value (IV) decreased with storage indicating some extent of oxidation of the unsaturated fatty acids, which increased by photooxidation in translucent packings (PP and PE) under the effect of light energy with minimum changes for MPP followed by PP, then the unsealed PE with maximum change due to exposure to the oxygen of air beside light energy. The oxidative stability index (OSI) decreased with storage but it was more stable for MPP followed by PP, then PE packings. Conjugated dienes and trienes increased with storage with minimum changes for MPP followed by PP, then PE packings.

**Table 1. Physicochemical quality parameters and effect of storage on date biscuits under different types of packing materials.**

| Parameter | Fresh | PE | | | PP | | | MPP | | | LSD |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Storage period (Days) | | | | | | | | | | |
| | 0 | 30 | 60 | 90 | 30 | 60 | 90 | 30 | 60 | 90 | |
| Refractive index (RI) | $1.4590^{a}$ | $1.4557^{a}$ | $1.4542^{a}$ | $1.4524^{a}$ | $1.4563^{a}$ | $1.4552^{a}$ | $1.4537^{a}$ | $1.4584^{a}$ | $1.4575^{a}$ | $1.4564^{a}$ | 0.0613 |
| Acidity (%) | $0.40^{cd}$ | $0.49^{bc}$ | $0.50^{b}$ | $0.52^{a}$ | $0.45^{fg}$ | $0.46^{ef}$ | $0.47^{de}$ | $0.40^{i}$ | $0.41^{hi}$ | $0.42^{h}$ | 0.0191 |
| Peroxide value (PV) | $0.30^{gh}$ | $0.56^{c}$ | $0.63^{b}$ | $0.84^{a}$ | $0.37^{fg}$ | $0.48^{d}$ | $0.55^{c}$ | $0.32^{ij}$ | $0.39^{f}$ | $0.43^{e}$ | 0.0205 |
| Iodine value (IV) | $51.50^{a}$ | $49.56^{ab}$ | $47.91^{bcd}$ | $46.31^{d}$ | $49.72^{ab}$ | $48.10^{bcd}$ | $46.54^{cd}$ | $49.89^{ab}$ | $48.55^{bc}$ | $46.90^{cd}$ | 2.0644 |
| Oxidative stability (hr.) | $16.90^{abc}$ | $15.80^{cde}$ | $15.28^{ef}$ | $14.75^{f}$ | $16.27^{abcd}$ | $15.90^{cde}$ | $15.60^{de}$ | $16.33^{abc}$ | $16.25^{abcd}$ | $16.15^{bcd}$ | 0.6751 |
| Diene | $0.019^{fg}$ | $0.035^{c}$ | $0.05^{b}$ | $0.062^{a}$ | $0.023^{fg}$ | $0.031^{d}$ | $0.034^{a}$ | $0.020^{h}$ | $0.024^{f}$ | $0.027^{e}$ | 0.0014 |
| Triene | $0.013^{g}$ | $0.022^{c}$ | $0.034^{b}$ | $0.040^{a}$ | $0.015^{h}$ | $0.019^{e}$ | $0.021^{d}$ | $0.012^{j}$ | $0.015^{h}$ | $0.017^{f}$ | 0.0009 |

Values are means of three replicates with LSD for each parameter.
Values number in the same row followed by different letters are significantly different at $P < 0.05$.
PE – Unsealed polyethylene; PP – Sealed polypropylene; MPP – Sealed metalized polypropylene

## Fatty acid composition of date biscuits under different types of packing materials

The fatty acid composition of date biscuits under different types of packing for freshly prepared biscuits compared to stored biscuits (90 days) are shown in Table 2. It is noticed significant differences between fresh and stored samples under different types of packing. ΣUSFA was 49.144%, 47.301%, 47.579%, and 48.233% for fresh, PE, PP, and MPP, respectively, whereas, ΣSFA was 50.856%, 52.699%, 52.421%, and 51.547% for fresh, PE, PP, and MPP, respectively, which reflects the effect of storage conditions such as moisture, air, and light which induced the lipid oxidation processes or enzymatic hydrolysis which affected the percent composition of the unsaturated fatty acids to a lesser content for stored samples, with minimum changes recorded for MPP, followed by PP, then PE which was highly affected by storage conditions. Also, ΣPUFA was 10.399%, 9.978%, 9.871%, and 10.010% for fresh, PE, PP, and MPP, respectively, with maximum values assigned for fresh samples a lesser content for stored samples, with minimum changes recorded for MPP, followed by PP, then PE which was highly affected by storage conditions. Also, ΣPUFA was 10.399%, 9.978%, 9.871%, and 10.010% for fresh, PE, PP, and MPP, respectively, with maximum values assigned for fresh samples before storage, then MPP followed by PP, then PE in the last position.

**Table 2. Fatty acid composition of date biscuits under different types of packing materials.**

| Fatty acid [%] | Fresh | PE | PP | MPP |
|---|---|---|---|---|
| | Storage period (Days) | | | |
| | 0 | 90 | 90 | 90 |
| $C_{12:0}$ | 0.176 | 0.186 | 0.153 | 0.190 |
| $C_{14:0}$ | 1.035 | 1.044 | 1.020 | 1.358 |
| $C_{16:0}$ | 44.400 | 45.899 | 45.650 | 44.466 |
| $C_{16:1}$ | 0.217 | 0.205 | 0.202 | 0.226 |
| $C_{17:0}$ | 0.104 | 0.108 | 0.106 | 0.096 |
| $C_{17:1}$ | 0.026 | 0.024 | 0.023 | 0.025 |
| $C_{18:0}$ | 4.638 | 4.938 | 4.982 | 4.889 |
| $C_{18:1}$ | 38.330 | 36.932 | 37.323 | 37.847 |
| $C_{18:2\ Trans}$ | 0.000 | 0.159 | 0.147 | 0.112 |
| $C_{18:2}$ | 9.991 | 9.621 | 9.535 | 9.695 |
| $C_{18:3}$ | 0.407 | 0.197 | 0.190 | 0.204 |
| $C_{20:0}$ | 0.427 | 0.437 | 0.434 | 0.375 |
| $C_{20:1}$ | 0.172 | 0.162 | 0.160 | 0.126 |
| $C_{22:0}$ | 0.077 | 0.087 | 0.077 | 0.172 |
| ΣSFA | 50.856 | 52.699 | 52.421 | 51.547 |
| ΣUSFA | 49.144 | 47.301 | 47.579 | 48.233 |
| ΣMUFA | 38.745 | 37.323 | 37.708 | 38.223 |
| ΣPUFA | 10.399 | 9.978 | 9.871 | 10.010 |

PE – Unsealed polyethylene; PP – Sealed polypropylene; MPP – Sealed metalized polypropylene; MUFA – Mono unsaturated fatty acid; PUFA – Poly unsaturated fatty acid; SFA – Saturated fatty acid; USFA – Unsaturated fatty acid

Considering the major unsaturated fatty acid; oleic acid ($C_{18:1}$) percent was 38.330%, 36.932%, 37.323%, and 37.847% for fresh, PE, PP, and MPP, respectively with maximum values recorded for MPP, followed by PP, then PE., which reflects the highest stability for MPP, whereas, the major saturated fatty acid; palmitic acid ($C_{16:0}$) percent was 44.400%, 45.899%, 45.650%, and 44.466% for fresh, PE, PP, and MPP, respectively with maximum values recorded for PE, followed by PP, then MPP. Although only slight changes occurred in the fatty acid composition, these changes indicated that lipid oxidation processes had already occurred. Considering *trans*-fatty acids, the fresh samples did not show any *trans*-fatty acids, whereas, the stored samples for 90 days under all packing materials, showed *trans*-fatty acid contents as 0.159%, 0.147%, and 0.112% for PE, PP, and MPP, respectively. The detected values for *trans*-fatty acids were below the official allowed limits, where the content of *trans*-fatty acid, in food intended for the final consumer and food intended for supply to retail, shall not exceed 2 grams per 100 grams of fat (Commission Regulation (EU) 2019/649). Combining the results of physicochemical analysis and fatty acid composition, it could be realized the superiority of MPP in providing the best protection against lipid oxidation processes with the extension of shelf life.

## Chemical migration testing of packing materials

The results of chemical migration testing of the three different types of packing are shown in Table 3.

## Standard migeration limits of chemical elements in packing materials

To quantify migration and risk of packing materials, concentrations of the measured chemical elements were compared with their migration limits according to the Commission Regulation (EU) No. 10/2011 by the ANNEX II: Plastic materials and articles shall not release the following substances in quantities exceeding the specific migration limits below:

Barium = 1 mg/kg food or food simulant.
Cobalt = 0.05 mg/kg food or food simulant.
Copper = 5 mg/kg food or food simulant.
Iron = 48 mg/kg food or food simulant.
Lithium = 0.6 mg/kg food or food simulant.
Lithium = 0.6 mg/kg food or food simulant.
Manganese = 0.6 mg/kg food or food simulant.

Zinc = 25 mg/kg food or food simulant.

Thereby, from the results summarized in Table 3., there were no chemical elements detected according to the limit of detection (LOD) of the analytical instrument which has been assigned as 0.01 ppm for all elements. There are no significant differences between the packing materials in chemical migration testing and all were safe for food packaging and will not result in hazardous toxic chemicals in measurable amounts according to the benchmark levels stipulated by the Commission Regulation (EU) No. 10/2011.

**Table 3. Chemical migration testing of different packing materials**

| After soaking in 10% ethyl alcohol for 20 days | | | |
|---|---|---|---|
| **Chemical element (ppm)** | **PE** | **PP** | **MPP** |
| Copper (Cu) | < LOD | < LOD | < LOD |
| Zinc (Zn) | < LOD | < LOD | < LOD |
| Manganese (Mn) | < LOD | < LOD | < LOD |
| Iron (Fe) | < LOD | < LOD | < LOD |
| Cobalt (Co) | < LOD | < LOD | < LOD |
| Barium (Ba) | < LOD | < LOD | < LOD |
| Lithium (Li) | < LOD | < LOD | < LOD |
| **After soaking in 3% acetic acid for 20 days** | | | |
| **Chemical element (ppm)** | **PE** | **PP** | **MPP** |
| Copper (Cu) | < LOD | < LOD | < LOD |
| Zinc (Zn) | < LOD | < LOD | < LOD |
| Manganese (Mn) | < LOD | < LOD | < LOD |
| Iron (Fe) | < LOD | < LOD | < LOD |
| Cobalt (Co) | < LOD | < LOD | < LOD |
| Barium (Ba) | < LOD | < LOD | < LOD |
| Lithium (Li) | < LOD | < LOD | < LOD |

PE – Unsealed polyethylene; PP – Sealed polypropylene; MPP – Sealed metalized polypropylene; LOD – Limit of detection (0.01 ppm)

Soaking the packing materials in 10% ethyl alcohol (Food simulant A) and 3% acetic acid (Food simulant B) represents the worst-case scenario for the migration of chemicals into fat-rich foods such as date biscuits. The migration level is expected to be lower in real food than in the applied simulants. Although there is a difference in the unit between the measured migration levels (ppm or mg/L) and the specific migration limits (mg/kg) stipulated by the Commission Regulation (EU) No. 10/2011, such difference in units can be ignored as the density of liquid food is generally set at 1 kg/L when performing migration test. Therefore, the unit mg/L or ppm can be directly converted to mg/kg without changing the experimental data. Considering the order of quality and safety of the used packing materials on date biscuits, it could be mentioned the superiority of MPP followed by PP and then PE, as proven by the physicochemical quality parameters coincided with research works mentioned that polyethylene (PE), the most commonly used plastic food packaging due to its low price with excellent mechanical properties and polypropylene (PP) with the highest consumption worldwide due to its versatility along with its good processability and relatively low cost, however, PE and PP cause serious problems due to their non-degradability and difficulty in disposal and recycling that might cause serious environmental issues as a generator of plastic pollution having negative environmental effects and not directed to be reused again in food packaging due to restrictions regulated by international agencies that are directly related to possible contamination of food from recycled material such as pesticides, cleaning products, and solvents compared with MPP which is widely used as a food packaging material maintaining the highest quality and safety (Zhang et al., 2022).

## Microbiological analysis of date biscuits under different types of packing materials

Date biscuits are manufactured from many ingredients including milk, fats, sugar, date paste, and cereal products which can be affected by microbial contamination resulting from bad storage conditions of raw materials such as air, moisture, and light with improper handling and unsanitary conditions during different steps of processing and packaging, leading to food intoxication with microbial growth of pathogenic microbial flora posing a serious risk on quality, safety, shelf life, and consumer's health. Microbiological analysis and the effect of storage on the microbiological activity under different types of packing materials are shown in Table 4. for fresh and stored date biscuits

(0, 30, 60, and 90 days). Results summarized in Table 4. show significant differences ($P < 0.05$) in the microbiological activity among date biscuits under different types of packing materials as affected also by the storage time (0, 30, 60, and 90 days).

The aerobic plate count (APC) and the total combined yeasts and molds count (TYMC) for fresh sample (0 days), PP, and MPP was < 10, whereas, PE had aerobic plate count (APC) of 390, 557, and 703 CFU/g for samples stored for 30, 60, and 90 days, respectively. days, respectively. Whereas, the total combined yeasts and molds count (TYMC) for PE samples was 90, 170, and 245 CFU/g for storage periods 30, 60, and 90 days, respectively.

APC and TYMC obtained in fresh, PP, and MPP samples at all storage periods were lower than the permitted range. PE showed considerably higher APC and TYMC after 30 days of storage, and after 60 days TYMC was higher than the maximum levels stipulated by the Egyptian Standards (Egyptian Standards, 2008) which mentioned that the total bacterial total count should not exceed $10^4$ CFU/g; yeast and molds count should not exceed 100 CFU/g in the biscuits for children.

**Table 4. Microbiological activity and effect of storage on date biscuits under different types of packing materials**

| Parameter | Fresh | PE | | | PP | | | MPP | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Storage period | | | Storage period (Days) | | | Storage period | | |
| | 0 | 30 | 60 | 90 | 30 | 60 | 90 | 30 | 60 | 90 |
| Aerobic plate count APC (CFU/g) | < 10 | 390 | 557 | 703 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Yeasts and molds count (CFU/g) | < 10 | 90 | 170 | 245 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| *Bacillus cereus* (CFU/g) | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| *E. coli* (CFU/g) | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| *Salmonella spp.* (per 25 g) | ← Absent → | | | | ← Absent → | | | ← Absent → | | |
| *Listeria spp.* (per 25 g) | ← Absent → | | | | ← Absent → | | | ← Absent → | | |

PE – Unsealed polyethylene; PP – Sealed polypropylene; MPP – Sealed metalized polypropylene

## Determination of aflatoxins and deoxynivalenol in date biscuits under different types of packing materials

Mycotoxins (aflatoxins and deoxynivalenol) are considered serious contaminants of food products with proven health risks. Therefore, the determination of aflatoxins and deoxynivalenol was carried out in date biscuits under different types of packing and the results were tabulated in Table 5.

From the results summarized in Table 5., for aflatoxins (B1, B2, G1, G2) and deoxynivalenol, the benchmark values assigned by Commission Regulation (EU) No 165/2010 for aflatoxins and Commission Recommendation (2006/576/EC) for deoxynivalenol.

**Table 5. Determination of aflatoxins and deoxynivalenol in date biscuits under different types of packing materials.**

| Compound | PE | PP | MPP |
|---|---|---|---|
| Aflatoxin B1 | < LOQ | < LOQ | < LOQ |
| Aflatoxin B2 | < LOQ | < LOQ | < LOQ |
| Aflatoxin G1 | < LOQ | < LOQ | < LOQ |
| Aflatoxin G2 | < LOQ | < LOQ | < LOQ |
| Deoxynivalenol | < LOQ | < LOQ | < LOQ |

PE – Unsealed polyethylene; PP – Sealed polypropylene;
MPP – Sealed metalized polypropylene
LOQ – Limit of quantitation (mentioned below)

These values (LOQ) were considerably less than the ranges permitted by the official regulations. Thereby, all the tested samples of date biscuits under different types of packing materials were safe for consumption as the aflatoxins and deoxynivalenol values did not reach the benchmark values assigned by Commission Regulation (EU) No 165/2010 for aflatoxins and Commission Recommendation (2006/576/EC) for deoxynivalenol. Also, there were no significant differences between date biscuits samples under different types of packing, and hence, there is no effect of packing materials on the contents of aflatoxins and deoxynivalenol.

## Determination of pesticides in date biscuits under different packing materials

The presence of pesticide residue in food products can lead to the continuous accumulation of harmful chemical residues which emerge in the food resulting in considerably high health risks with negative impacts on the environment and living organisms. Therefore, the determination of pesticide residue in food products is considered a very important analysis. Table 6. summarizes the results of the analysis of pesticide residue in date biscuits under different types of packing materials.

**Table 6. Determination of pesticides in date biscuits under different types of packing materials.**

| Compound (mg/kg) | PE | PP | MPP |
|---|---|---|---|
| Acetamiprid | 0.018 | 0.018 | 0.018 |
| Piperonyl butoxide | 0.013 | 0.013 | 0.013 |
| Thiamethoxam | 0.011 | 0.011 | 0.011 |
| Chlorpyrifos | < LOQ | < LOQ | < LOQ |
| Primiphos-methyl | 0.011 | 0.011 | 0.011 |

PE – Unsealed polyethylene; PP – Sealed polypropylene; MPP – Sealed metalized polypropylene
LOQ – Limit of quantitation (0.01 mg/kg)

Pesticide residue content results in Table 6. were found lower than the permitted ranges (where the maximum residues levels MRLs are the maximum concentrations of pesticide residue in foods that are legally tolerated) stipulated by the Commission Regulation (EU) 2014/87 for Acetamiprid; Regulation (EC) No 396/2005 for Piperonyl butoxide; Commission Regulation (EU) 2016/156 for Thiamethoxam; Commission Regulation (EU) 2020/1085 for Chlorpyrifos; Commission Regulation (EU) 2016/53 for Primiphos-methyl. Also, there were no significant differences between date biscuits samples under different types of packing, and hence, there is no effect of packing materials on the contents of pesticides and all the tested samples were safe for consumption.

## Sensory evaluation of date biscuits under different types of packing materials

Sensory evaluation is considered a very important step for the improvement of food processing, packaging, and marketing to avoid product failure in the whole market due to defects in its organoleptic attributes emerging from the interaction between the physical and chemical components of the food with the different human sense organs. Therefore, manufacturers carry out sensory evaluations for their products to assure their acceptance by consumers along with the development of new reliable processing methodologies for food products.

**Table 7. Sensory evaluation of date biscuits under different types of packing materials**

| Sensory attribute | PE | PP | MPP | LSD |
|---|---|---|---|---|
| Appearance | $7.16^{c}$ | $7.82^{b}$ | $8.84^{a}$ | 0.26 |
| Aroma | $7.07^{c}$ | $7.27^{b}$ | $8.72^{a}$ | 0.38 |
| Taste | $7.17^{c}$ | $7.46^{b}$ | $8.63^{a}$ | 0.46 |
| Texture | $7.22^{c}$ | $7.54^{b}$ | $8.87^{a}$ | 0.52 |
| Overall Acceptability | $7.16^{c}$ | $7.52^{b}$ | $8.77^{a}$ | 0.41 |

PE – Unsealed polyethylene; PP – Sealed polypropylene; MPP – Sealed metalized polypropylene
Values are means of ten replicates with LSD for each parameter. Values number in the same row followed by different letters are significantly different at P < 0.05.

Sensory evaluation of date biscuits under different types of packing materials as shown in Table 7., was carried out after 30 days of storage of products to study the effect of the application of packing materials that have been in contact with food for an effective time. From the results of sensory evaluation summarized in Table 7., significant differences ($P < 0.05$) existed among the three different packing materials (PE, PP, and MPP) used in the study, which reflect the effect of different backing materials on the organoleptic attributes of food products. Considering the effect on appearance, aroma, taste, texture, and overall acceptability, MPP had the highest overall overall score (8.77) in protecting original color, aroma, taste, and texture, followed by PP (7.52), then PE (7.16) as the least overall score of sensory evaluation.

Despite the higher price and manufacturing cost of MPP compared with the relatively cheap PE and PP, MPP is widely used as a food packaging material maintaining the highest quality and safety, as the aluminum layer in the metalized packing is directly applied onto the polymer surface of the packing material through vacuum deposition without using any adhesives, compared to common laminated multilayer films packing materials which use adhesives to adhere the aluminum foil to the polymer, causing potential migration of toxic chemicals from the adhesive layer to a food matrix, rendering potential health risks. MPP had the best characteristics for providing the optimum protection for fat-rich foods against rancidity and deterioration resulting from the lipid oxidation processes, through its tightly sealed opaque (non-translucent) structure which protects food products against air, moisture, and light energy which induce the photo-oxidation processes (Zhang et al., 2022). The superiority of MPP as a packing material for date biscuits agreed with the aforementioned results of the physicochemical analysis, fatty acid composition, and microbiological analysis which confirmed the highest quality and safety of MPP for providing the most efficient protection against lipid oxidation and deterioration of date biscuits with highest storage stability and shelf life.

## 4. Conclusions

Due to the increasing interest in the treatment of malnourished children using functional date biscuits as a common food fortified with nutraceuticals, the objective of the current research paper was to study the lipid oxidation processes occurring in date biscuits due to their considerable fat content under different types of packing materials to show the effect of different packing materials on the quality and safety of date biscuits to reach the superior packing material for maintaining the highest quality and safety of products, considering the lipid oxidation processes and the shelf life of products. Physicochemical, microbiological, and sensory evaluation results showed that the sealed metalized polypropylene (MPP) packing was the most protective against lipid oxidation with the highest shelf life of date biscuits.

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