Impact of Package Type and Jojoba Oil Addition on the Physicochemical Properties and Microbial Quality of Caraway Fruits During Storage

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ABSTRACT

This study aimed to investigate the effect of package type and jojoba oil addition on the quality parameters of caraway fruits (*Carum carvi* L.) during storage at ambient temperature for 20 months. The packages used in the study were low-density polyethylene (LDPE) bags (control), LDPE bags treated with a layer of jojoba oil (LDPE-JO), high-density polyethylene (HDPE) containers (transparent and dark), and glass bottles (transparent and dark). Moisture content, weight loss, essential oil (EO) content, EO composition (using GC), flavor, and microbial counts of caraway fruits during storage were investigated. The results showed that weight loss and carvone content increased, while moisture content, EO content, and limonene content decreased gradually during storage. Also, a slight decrease in flavor scores of all samples was observed during storage. No microbial growth was detected for all samples during the storage period. The sample packaged in LDPE-JO bags was more stable during storage compared to other packages in terms of moisture content, weight loss, EO content, EO composition, and flavor. Generally, caraway packaged in LDPE-JO bags was the best among all packages used during the storage period.

Keywords: Caraway, jojoba oil, microbial counts, packaging, storage.

INTRODUCTION

Caraway (*Carum carvi* L.) is one of the most important medicinal and aromatic plants in Egypt in terms of cultivated area that was 12691 fed. (BAS, 2019). According to the European Union Herbal Monograph, caraway is traditionally used for symptomatic relief of digestive disorders such as bloating and flatulence. Caraway fruits are also used to flavor the rye bread, remedy the digestive disorders, and fight the worms (Attokaran, 2017). Caraway possesses stimulant, expectorant and antispasmodic effects and is used for stomach aches, constipation, and nausea. It has digestive stimulatory effects i.e. it increases the secretion of gastric juice and promotes the discharge of bile, which in turn increases the appetite (Peter, 2006).

Carvone and limonene are the two major components that represent 95% of the total essential oil (EO) content in caraway. According to European Pharmacopoeia, caraway fruits should contain 3% EO including D-carvone (50–65%) and limonene (35–45%) with less than 1.5% carveol and dihydrocarveol. D-carvone, the main component of caraway (Ravid *et al*., 1992), is responsible for caraway odor reminiscent (de Carvalho & da Fonseca, 2006). Caraway EO has been reported to have antimicrobial and antioxidant activities (Kamaleeswari & Nalini, 2006, Rodov *et al*., 2010). The EO of caraway has stronger antifungal and antibacterial effects than citronella EO (Simic *et al*., 2008). The antioxidant, antimicrobial, and anti-aflatoxigenic effects of caraway EO along with its reputation as spice encourage its usage as a natural preservative and antioxidant agent (Mahboubi, 2019).

However, several studies reported that the EO's content and limonene to carvone ratio of caraway were changed during storage (Sedlakova *et al*., 2001). Eid (1999) observed a gradual decrease in the EO content of coriander and caraway fruits stored for 18 months in polyethylene, card box, and jute containers. Likewise, Badei *et al*. (2000) noticed a significant decrease in the EO content of biscuits made with caraway and cumin EO during storage at room temperature for 8 months. Also, El-Moghazy (2013) reported that the extended storage of spearmint and peppermint for 12 months resulted in a reduction of the EO percentage and limonene and carvone content of the two herbs. Abd El-Aleem & Hamed (2018) studied the storage stability of *Mentha spicata*. They observed a decrease in EO percentage and limonene content with an increase in the carvone content, then the concentration of carvone was decreased after four months of storage.

Yousef & Hamouda (2013) found that the use of glass jar as packing container was the best for maintaining the EO content of thyme herb during storage for 12 months. El-Moghazy (2013) reported that polyethylene bag, among all the tested packages, showed superiority for keeping the quality of the packaged product. The least loss in EO percentage of *Mentha spicata* L. was achieved by using polyethylene bag followed by kraft paper bag, polypropylene bag, and linen bag (Abd El-Aleem & Hamed, 2018).

Jojoba oil is almost colorless and odorless oil, it is composed of straight-chain monoesters in the range of Cl8–C24 of alcohols and unsaturated fatty acids. It is not digested by the human lipase enzymes, therefore, it could be considered as a promised low-energy alternative to traditional oils. It showed a high resistance to rancidity with good oxidative stability at high temperatures up to 110˚C. It is vastly used in cosmetic and pharmaceutical applications. Regarding the folk medicine, jojoba oil was used as a remedy for cancer, kidney disorders, acne, eczema, psoriasis, wounds, headache, and sore throat. In addition, it has an antimicrobial, antiparasitic and anti-inflammatory effects. Previous studies showed several applications of jojoba oil in food industry e.g. margarine, mayonnaise, and coating of foodstuffs, which clearly enhanced their stability compared to hydrogenated oils (Verschuren, 1989, Farag *et al.,* 2008). It has been reported that the EO and various extracts from jojoba seeds can be used as natural preservatives in food against the well-known causal agents of food-borne diseases and food spoilage (Al-Reza, *et al*., 2010). The antimicrobial packaging systems reduced the population of bacteria in foods, such systems require further studies to make them more effective for industrial applications (Cooksey, 2005). The objective of this work was to evaluate some types of packing containers and to study the impact of jojoba oil on the quality of caraway during storage for 20 months at ambient temperature.

MATERIALS AND METHODS

Raw materials and experimental design

This work was carried out at Sabahia, Hort. Res. Station, Alexandria, Egypt. Dried caraway fruits (*Carum carvi* L.) were obtained from a private farm in Kom Hamada, Beheira, Egypt. The packages used in the study were low-density polyethylene (LDPE) bags (control), LDPE bags treated with a layer of jojoba oil (LDPE-JO) i.e. the bags were painted from inside with around 1 mL of jojoba oil using a small brush, high-density polyethylene (HDPE) containers (transparent and dark), and glass bottles (transparent and dark). The packages were filled with 100 g of dried caraway samples and stored at room temperature (24±2˚C) for further analysis (Fig.1). Samples were evaluated every four months in terms of moisture content, weight loss, essential oil (EO) content, EO composition (using GC), flavour, and microbial counts during storage for 20 months (from 1/6/2018 to 30/1/2020). The complete randomized design with six treatments, six intervals, and three replicates was applied.

Moisture content

The moisture content of stored caraway samples was determined every four months by oven drying method using the standard procedures of AOAC (2006).

Weight loss

The weight loss of stored caraway samples was estimated every four months gravimetrically using a digital weighing balance.

Determination of EO content

A sample of 100 g of caraway fruits was subjected to hydro-distillation for 3 hr using a Clevenger apparatus. Essential oil content was calculated as a relative percentage (v/w) according to the procedure described by the Egyptian Pharmacopoeia (2005). Oils were dried by anhydrous sodium sulfate and stored in dark vials at 4˚C for further analysis.

Determination of EO composition using Gas Chromatography (GC)

The GC analysis was carried out using DS 6200 Gas Chromatograph with BPX5 capillary column and a flame ionization detector under the following operating conditions: a sample size of 1 µl and temperature increasing rate of 10˚C/min (from 70˚C to

Fig. 1. Caraway fruits stored at room temperature in different types of packages: (A), low density polyethylene (LDPE) bags (control); (B), LDPE bags treated with a layer of jojoba oil (LDPE-JO); (C), transparent glass bottles; (D), dark glass bottles; (E), transparent high density polyethylene (HDPE) containers; (F), dark HDPE containers.

200˚C). The carrier gases were nitrogen, hydrogen, and air with a flow rate of 30, 30, and 300 mL/min, respectively. Main compounds of the volatile oils were identified by matching their retention times with those of the authentic samples injected under the same conditions. The percentage of EO components were obtained by calculating the area under the peak appeared for each compound.

Sensory evaluation

The hot drinks of caraway samples were prepared and evaluated by10 panellists for flavor using a nine-point hedonic scale (from like extremely = 9 to dislike extremely = 1) according to Ranganna (1986).

Microbiological analysis

Samples of 10 g were mixed in 90 mL of sterilized physiological solution (0.85% NaCl), various dilutions were prepared to determine the total bacterial counts (TBC) and yeast and mold counts. TBC was determined using Plate Count Agar medium (PCA, OXOID, CM325), which was cooked, dispense into flasks, and autoclaved at 121˚C for 20 min, about 1 mL of diluted sample was added to the warm sterilized medium and incubated for 3 days at 37˚C according to der Steen *et al*. (2002). Yeast and mold counts were determined by plating 0.1 mL of diluted sample on Rose Bengal Chloramphenicol medium (VRBGA, OXOID, CM485) and incubated for 5 days at 25˚C according to Voon *et al*. (2006). All samples were investigated in triplicates. The microbial population was expressed as the logarithm of colony-forming units per gram of caraway samples (log cfu/gm).

Statistical analysis

The obtained data were statistically analyzed using analysis of variance (ANOVA). The LSD was calculated to estimate the significant differences ($P < 0.05$) using statistical software (CoStat, version 6.303, 2005) according to Gomez & Gomez (1984).

RESULTS AND DISCUSSION

Chemical composition of EO and microbial load of caraway fruits before storage

The EO content of caraway fruits and its chemical composition before storage are given in Table (1). The EO content was 2.65%, it contained 44.73% limonene and 54.00% carvone. These results are close to those reported by Meshkatalsadat *et al*. (2012). They reported that caraway fruits contained 35.50 and 57.70% of limonene and carvone, respectively with 0.31 and 0.33% of carveol and dihydrocarvone, respectively. Based on the microbiological examinations, no microbial growth was observed for caraway samples. This could be due to the strong antimicrobial and antifungal effects of the EO of caraway fruits as reported by several studies (Simic, *et al*., 2008, Hassan *et al*., 2020). They asserted the efficiency of caraway EO against different strains of bacteria, yeasts, and molds.

Moisture content and weight loss

The effects of package type, storage period, and their interactions on the moisture content and weight loss of caraway are presented in Tables (2) and (3), respectively. It could be noted that the moisture content and weight of all samples decreased significantly ($P < 0.05$) during storage. Our results are

Table 1: Essential oil content, chemical composition, and microbial counts of caraway fruits before storage.

Parameter	(%)
Moisture content	7.95
Essential oil content	2.65
Essential oil composition	
Limonene	44.73
Carvone	54.00
Dihydrocarveol	0.39
Carveol	0.38
Other components	0.50
(Microbial load	**(log cfu/gm)**
Total aerobic bacterial counts	ND
Total fungi (yeast and molds) counts	ND

ND = not detected.

similar to those reported by other researchers (Abd El-Aleem & Hamed, 2018) who observed a decrease in the weight of mint samples during storage at ambient temperature. The decrease in the samples' weight during storage may be due to the loss of some components by evaporation, particularly moisture and EO. Among all packages, the control showed the highest weight loss, whereas the caraway samples packaged in LDPE-JO bags showed the lowest. Samples stored in dark glass bottles showed better storage stability, in terms of moisture content and weight loss, compared to those stored in transparent glass bottles. Also, samples stored in dark HDPE packages were more stable than those stored in transparent HDPE packages. It is worth to note that the dark packages have a photoprotective effect against photo-oxidation reactions. Since packages differ in their permeability, this may have been responsible for the differences in the moisture con-

Table 2: Effect of package type and storage period on moisture content (%) of caraway fruits stored at room temperature for 20 months.

Treatments	Storage time (Months)						
	0	4	8	12	16	20	Means
LDPE bags (control)	7.95	7.79	6.92	6.53	6.21	6.02	6.90
LDPE-JO bags	7.95	7.95	7.95	7.90	7.87	7.82	7.90
Transparent HDPE containers	7.95	7.84	7.54	7.11	6.65	6.44	7.25
Dark HDPE containers	7.95	7.95	7.80	7.52	7.15	6.81	7.53
Transparent glass bottles	7.95	7.95	7.86	7.81	7.78	7.71	7.84
Dark glass bottles	7.95	7.95	7.95	7.89	7.86	7.80	7.90
Means	7.95	7.90	7.67	7.46	7.25	7.10	
LSD at $_{0.05}$	T = 0.15		S = 0.15	T×S = 0.38			

Abbreviations: LSD, least significant difference ($P < 0.05$), T, treatments, S, storage time, T×S, interaction.

Table 3: Effect of package type and storage period on the weight loss (g) of caraway fruits stored at room temperature for 20 months.

Treatments	Storage time (Months)						
	0	4	8	12	16	20	Means
LDPE bags (control)	100.00	99.78	98.62	97.75	96.90	96.44	98.24
LDPE-JO bags	100.00	100.00	100.00	99.93	99.87	99.81	99.93
Transparent HDPE Containers	100.00	99.86	99.32	98.79	98.36	97.93	99.04
Dark HDPE Containers	100.00	100.00	99.75	99.21	98.52	98.14	99.27
Transparent glass bottles	100.00	100.00	99.87	99.74	99.71	99.65	99.82
Dark glass bottles	100.00	100.00	100.00	99.92	99.84	99.80	99.92
Means	100.00	99.94	99.59	99.22	98.86	98.62	
LSD at $_{0.05}$	T = 0.19		S = 0.19		T×S = 0.48		

Abbreviations: LSD, least significant difference ($P < 0.05$), T, treatments, S, storage time, T×S, interaction.

tent and weight loss between samples. Moreover, it could be suggested that jojoba oil improved the barrier properties of the packages leading to better storage stability in terms of moisture content and weight loss. The barrier properties of LDPE-JO bags were similar to those of glass packages. Regarding the effect of storage time, the moisture content and weight of caraway samples were almost stable for the first four months and decreased gradually in all samples up to the end of storage. The results revealed that the effects of the interaction were statistically (P<0.05) significant. The trends obtained for the effects of storage time and package type on the weight loss of caraway samples in the current study were in harmony with those obtained previously (Ahmed *et al*., 2016) for dry leaves of the basil plant.

EO content

Changes in the EO content of caraway fruits stored at room temperature in different types of packages are displayed in Table (4). The results showed that EO content of all samples, except the control, was almost stable during the first four months, then decreased significantly ($P < 0.05$) by extending the storage period. Our findings were consistent with those reported by Ebadi *et al*. (2017) who recorded a decrease in the EO content of lemon verbena leaves during storage at ambient temperature. During storage, the samples packed in LDPE-JO bags showed the highest storage stability in terms of EO content, whereas the control showed the lowest. Additionally, samples stored in dark glass bottles showed better storage stability regarding EO content compared to those stored in transparent glass bottles. Likewise, samples stored in dark HDPE packages were more stable than those stored in transparent HDPE packages, which could be due to the protective effect of dark packages against photo-oxidation reactions. However, the results showed that the effects of the interaction were insignificant. Abd El-Aleem & Hamed (2018) studied the effect of storage conditions on the dry leaves of *Mentha spicata*. They reported that the lowest reduction in EO content was recorded for polyethylene bags followed by kraft paper bags, polypropylene bags, and linen bags. Yousef & Hamouda (2013) found that thyme samples stored in glass jars were the best among all tested samples in terms of keeping their EO content. The reduction of EO content during storage was also reported for anise hyssop (*Agastache foeniculum*) by Mahmoodi Sourestani *et al*. (2014). Such reduction of EO content during storage may be due to the evaporation and oxidative reactions (Rowshan *et al*., 2013). Generally, it could be observed that jojoba oil improved the barrier properties of the LDPE packages. Hence, it could be suggested that LDPE-JO bags may be used as a suitable alternative to glass packages as it is lower in cost, lighter in weight, and non-breakable.

EO composition

The effects of package type and storage periods on the chemical composition of EO of caraway fruits are presented in Table (5). The GC results showed noticeable changes in the percentages of the EO components during storage. Generally, the EO of caraway fruits contained 44.73 and 54.00%

Table 4: Effect of package type and storage period on essential oil content (%) of caraway fruits stored at room temperature for 20 months.

Treatments	Storage time (Months)						
	0	4	8	12	16	20	Means
LDPE bags (control)	2.65	2.59	2.56	2.55	2.51	2.48	2.55
LDPE-JO bags	2.65	2.65	2.61	2.60	2.58	2.58	2.61
Transparent HDPE containers	2.65	2.63	2.58	2.56	2.52	2.51	2.57
Dark HDPE containers	2.65	2.64	2.60	2.57	2.54	2.53	2.58
Transparent glass bottles	2.65	2.64	2.58	2.58	2.54	2.54	2.58
Dark glass bottles	2.65	2.65	2.62	2.61	2.59	2.57	2.61
Means	2.65	2.63	2.59	2.57	2.54	2.53	
LSD at $_{0.05}$	T = 0.03		S = 0.03		T×S = NS		

Abbreviations: LSD, least significant difference (P < 0.05), T, treatments, S, storage time, T×S, interaction, NS, not significant.

Table 5: Effect of package type and storage period on essential oil constituents (%) of caraway fruits stored at room temperature for 20 months.

Compounds (%)	Treatments	Storage time (Months) 0	4	8	12	16	20	Means
Limonene	LDPE bags (control)	44.73	40.43	35.12	33.00	32.63	31.79	36.28
	LDPE-JO bags	44.73	43.81	41.92	40.09	38.77	38.06	41.23
	Transparent HDPE Containers	44.73	42.05	38.50	36.50	35.05	33.61	38.40
	Dark HDPE Containers	44.73	42.62	40.59	38.11	36.25	35.42	39.62
	Transparent glass bottles	44.73	43.67	41.52	39.12	38.45	37.57	40.84
	Dark glass bottles	44.73	44.10	43.22	41.66	39.58	38.75	42.00
	Means	44.73	42.78	40.14	38.08	36.78	35.86	
	LSD at $_{0.05}$	T = 0.16		S = 0.16		T×S = 0.41		
Carvone	LDPE bags (control)	54.00	58.32	63.01	65.05	66.17	67.03	62.26
	LDPE-JO bags	54.00	55.17	56.83	57.98	59.85	60.73	57.42
	Transparent HDPE Containers	54.00	56.59	59.88	62.39	63.65	65.14	60.27
	Dark HDPE Containers	54.00	56.15	58.22	60.63	62.55	63.64	59.20
	Transparent glass bottles	54.00	55.35	56.95	58.43	59.72	60.84	57.54
	Dark glass bottles	54.00	54.82	55.64	57.81	59.13	59.86	56.87
	Means	54.00	56.06	58.42	60.38	61.84	62.87	
	LSD at $_{0.05}$	T = 0.22		S = 0.22		T×S = 0.55		
Dihydro-carvone	LDPE bags (control)	0.39	0.48	0.55	0.57	0.57	0.58	0.52
	LDPE-JO bags	0.39	0.43	0.44	0.46	0.46	0.47	0.44
	Transparent HDPE Containers	0.39	0.46	0.50	0.52	0.53	0.54	0.49
	Dark HDPE Containers	0.39	0.45	0.49	0.51	0.51	0.52	0.47
	Transparent glass bottles	0.39	0.44	0.46	0.47	0.48	0.48	0.45
	Dark glass bottles	0.39	0.43	0.45	0.46	0.46	0.47	0.44
	Means	0.39	0.44	0.48	0.49	0.50	0.51	
	LSD at $_{0.05}$	T = 0.05		S = 0.05		T×S = NS		
Carveol	LDPE bags (control)	0.38	0.35	0.33	0.32	0.32	0.31	0.33
	LDPE-JO bags	0.38	0.37	0.37	0.36	0.36	0.35	0.36
	Transparent HDPE Containers	0.38	0.36	0.34	0.34	0.33	0.32	0.34
	Dark HDPE Containers	0.38	0.36	0.35	0.35	0.34	0.33	0.35
	Transparent glass bottles	0.38	0.37	0.36	0.36	0.35	0.34	0.36
	Dark glass bottles	0.38	0.38	0.37	0.36	0.36	0.35	0.36
	Means	0.38	0.36	0.35	0.34	0.34	0.33	
	LSD at $_{0.05}$	T = 0.03		S = 0.03		T×S = NS		
Other components	LDPE bags (control)	0.50	0.45	0.43	0.41	0.39	0.38	0.42
	LDPE-JO bags	0.50	0.48	0.48	0.47	0.46	0.46	0.47
	Transparent HDPE Containers	0.50	0.46	0.44	0.42	0.42	0.41	0.44
	Dark HDPE Containers	0.50	0.47	0.45	0.44	0.43	0.42	0.45
	Transparent glass bottles	0.50	0.48	0.47	0.47	0.46	0.45	0.47
	Dark glass bottles	0.50	0.49	0.48	0.48	0.47	0.46	0.48
	Means	0.50	0.47	0.45	0.44	0.43	0.43	
	LSD at $_{0.05}$	T = 0.04		S = 0.04		T×S = NS		

Abbreviations: LSD, least significant difference ($P < 0.05$), T, treatments, S, storage time, T×S, interaction, NS, not significant.

of limonene and carvone, respectively as they represent the two principal components. For all samples, limonene content decreased and carvone content increased by extending the storage period. Our results are in harmony with the findings reported for mint by Abd El-Aleem & Hamed (2018). They observed a decrease in limonene content and an increase in carvone content by extending the storage duration, which could be related to the conversion of limonene to carvone during storage. It could be noted that the caraway samples packed in dark glass bottles and LDPE-JO bags showed the highest storage stability in terms of EO composition, whereas the control showed the lowest. Moreover, samples stored in dark glass bottles showed better storage stability than those stored in transparent glass bottles. Also, samples stored in dark HDPE packages were more stable than those stored in transparent HDPE packages. However, the dark packages have a protective effect against photo-oxidation reactions. Yousef & Hamouda (2013) found that using glass jars as packing material were the best for keeping the EO composition of stored thyme herb. In addition, using polyethylene packages extended the storage period of spearmint and peppermint and kept the EO composition for longer time (El-Moghazy, 2013). Under specific conditions, some volatile compounds may migrate into the packaging material, which can make changes in the levels of EO components (Chaliha *et al*., 2013). In general, the changes of EO composition during storage may be related to the water content of the product, the type of compounds presented in the EO, the plant species, the storage conditions including the presence of oxygen, light, and temperature (Mahmoodi Sourestani *et al*., 2014, Ebadi *et al*., 2017).

Sensory evaluation

The changes in the flavor of caraway fruits stored at room temperature in different types of packages are presented in Table (6). The results revealed that the flavor of all samples, except the control, were almost stable during the first eight months of storage, then decreased significantly ($P < 0.05$) by extending the storage period. It could be noted that the sample packed in LDPE-JO bag showed the highest storage stability in terms of flavor, whereas the control showed the lowest. The decrease in flavor scores could be due to the reduction of EO content during storage, which in turn may be related to the evaporation and oxidative reactions (Rowshan *et al*., 2013). Generally, it could be suggested that jojoba oil improved the barrier properties of the LDPE packages, that maintained the EO content, which in turn saved the flavor of caraway during storage. Since jojoba oil is almost colorless and odorless oil (Verschuren 1989), no negative effects of jojoba oil on the flavour of caraway samples were observed during storage. Moreover, samples stored in dark glass bottles showed better storage stability compared to those stored in transparent glass bottles. Likewise, caraway stored in dark HDPE packages revealed better storage stability than those stored in transparent HDPE packages, which could be due to the protective effect of dark packages against oxidation reactions stimulated by light.

Microbial counts

It was clear that all caraway samples were free of microbial growth during storage including bacteria and fungi. The total aerobic bacterial counts, as well as total fungal (yeast and mold) counts, were

Table 6: Effect of package type and storage period on flavour of caraway fruits stored at room temperature for 20 months

Treatments	Storage time (Months)						
	0	4	8	12	16	20	Means
LDPE bags (control)	8.84	8.37	7.71	7.23	6.82	6.55	7.58
LDPE-JO bags	8.84	8.84	8.77	8.38	8.07	7.76	8.44
Transparent HDPE containers	8.84	8.79	8.44	8.00	7.53	7.02	8.10
Dark HDPE containers	8.84	8.84	8.54	8.08	7.68	7.19	8.19
Transparent glass bottles	8.84	8.84	8.63	8.14	7.75	7.38	8.26
Dark glass bottles	8.84	8.84	8.73	8.32	8.01	7.64	8.39
Means	8.84	8.75	8.47	8.02	7.64	7.25	
LSD at $_{0.05}$	T = 0.15		S = 0.15		T×S = 0.38		

Abbreviations: LSD, least significant difference ($P < 0.05$), T, treatments, S, storage time, T×S, interaction.

zero from the beginning of the experiment up to the end of the storage duration (data are not shown). The EO of the caraway fruits contains various compounds, mainly carvone and limonene, with strong antibacterial and antifungal effects, which may have been responsible for the absence of microbial growth during storage. The antibacterial and antifungal effects of caraway fruits were confirmed by several authors (Seidler-Łożykowska *et al*., 2013, Ghafari *et al*., 2014, Akram *et al*., 2019, Hassan *et al*., 2020). Moreover, the lower moisture content of the caraway fruits during storage may prevent the growth of microbes, particularly fungi which are more tolerant to the lower water activity than bacteria. Also, the packing containers were good for preserving the caraway fruits during storage. Additionally, it has been reported that the EO and various extracts of jojoba seeds can be used as natural preservatives in foods against a wide range of microorganisms causing foodborne illnesses and food spoilage (Al-Reza, *et al*., 2010). The EO of caraway showed stronger antifungal and antibacterial effect than that of citronella (Simic, *et al*., 2008). The antioxidant, antimicrobial, and anti-aflatoxigenic effects of caraway EO may confirm its potential use as natural preservatives and antioxidant agents (Mahboubi, 2019).

CONCLUSION

The impacts of package type on the quality parameters of caraway fruits stored at ambient temperature for 20 months were investigated. The samples packaged in LDPE-JO bags were more stable during storage compared to other packages in terms of moisture content, weight loss, EO content, EO composition, and flavor. Moreover, samples stored in dark packages showed better storage stability compared to those stored in transparent ones. The control showed the lowest storage stability in terms of all estimated parameters. No microbial growth was detected for all samples during the storage period. Generally, it could be observed that jojoba oil improved the barrier properties of the LDPE packages. Accordingly, this study suggests that LDPE-JO could be used as a suitable alternative to glass packages as it is cheaper, lighter, and non-breakable.

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تأثير نوع العبوة وإضافة زيت الجوجوبا على الخصائص الفيزيائية والكيماوية والجودة الميكروبية لثمار الكراوية أثناء التخزين

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يهدف هذا البحث إلى دراسة تأثير نوع العبوة وإضافة زيت الجوجوبا على جودة ثمار الكراوية (*Carum carvi* L) أثناء التخزين على درجة حرارة الغرفة لمدة ٢٠ شهرًا. استخدمت في الدراسة عبوات من أكياس بولي إيثيلين منخفضة الكثافة LDPE (كونترول) وأكياس LDPE مُعاملة بطبقة من زيت الجوجوبا LDPE–JO وعبوات بولي إيثيلين عالية الكثافة HDPE (شفافة ومعتمة) ، وعبوات زجاجية (شفافة ومعتمة). تم تتبع التغير في محتوى الرطوبة والفقد في الوزن ومحتوى الزيت العطري EO وتركيب الـ EO (باستخدام كروماتوجرافيا الغاز) والنكهة والحمل الميكروبي لثمار الكراوية طوال فترة التخزين. أظهرت النتائج زيادة الفقد في الوزن وزيادة محتوى الكارفون بينما قل المحتوى الرطوبي ومحتوى EO ومحتوى الليمونين تدريجياً أثناء التخزين. كما لوحظ انخفاض طفيف في قيم النكهة لجميع العينات أثناء التخزين. لم يكن هناك أي نمو ميكروبي لجميع العينات خلال فترة التخزين. كانت العينة المعبأة في أكياس LDPE–JO أكثر ثباتًا أثناء التخزين مقارنة بالعبوات الأخرى من حيث محتوى الرطوبة وفقدان الوزن ومحتوى EO وتركيب EO والنكهة. بشكل عام كانت الكراوية المعبأة في أكياس LDPE–JO هي الأفضل بين جميع العبوات المستخدمة خلال فترة التخزين.