

Effect of different types of plastic packaging films on the moisture and aflatoxin contents of pistachio nuts during storage

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Abstract Pistachio nut (*Pistacia vera* L.) is one of the popular tree nuts in the world. Proper selection of packaging materials is necessary to prevent absorption of moisture and aflatoxin formation which will influence the overall product quality and safety. This research is undertaken to study the effect of different type of flexible packaging films on the moisture and aflatoxin contents of whole pistachio nuts during storage at ambient temperature (22–28 °C) and relative humidity of 85–100%. Five types of plastic films tested were low density polyethylene (LDPE) which serves as the control, food-grade polyvinyl chloride (PVC), nylon (LDPE/PA), polyamide/polypropylene (PA/PP) and polyethylene terephthalate (PET). The moisture content and aflatoxin content of pistachio nuts were measured using oven drying method and HPLC, respectively. Sample were analysed at 0, 2, 4, 6, 8 and 10 months during the storage period. Results showed that there was an increase in moisture content with the increase in storage time of pistachio nuts. The increase in moisture content was associated with the aflatoxin level of pistachio nuts during storage time. All the packaging materials except LDPE delayed the moisture absorption and aflatoxin formation of the product. The most suitable packaging materials for maintaining the quality and safety of pistachio nuts is PET films followed by nylon, PA/PP and PVC. The shelf-life of pistachio can be extended from 2 months (Control) to 5 months when PET is used as the packaging material.

Keywords Pistachios · Packaging materials · Moisture content · Aflatoxin · Quality

Pistachio nut is one of the well-known nuts in the international markets. Iran is the main producer and exporter of pistachio nut in the world. Unsuitable packaging material and condition influences the quality of pistachio and acts as an obstacle for development of exports. When pistachio nut is kept at temperature less than 10 °C and relative humidity of less than 40%, there will be no possibility of fungi growth and aflatoxin production and shelf life of the product will be increased. There are several reasons for packaging of food materials, depending on product features. Among the advantages of packaging include protecting product physically, preventing spoilage and attracting customers. In case of seeds and nuts, the most sensitive and critical issue is the contamination to aflatoxin. Thus, there is serious need for ensuring that it is of high quality and safe for consumption.

One of the most important factors for pistachio during storage is its moisture absorption rate. Even though moisture content of pistachio nut is generally less or equal to 35% after soft hull splitting, the environmental condition is suitable for *A. flavus* contamination as it could compete successfully with other microorganisms to increase its population (Moradi and Javanshah 2006). Therefore, it is necessary to protect pistachio nut against all changes in environmental condition, otherwise the risk of fungi growth which causes spoilage and undesirable changes in taste is very high. Contamination to *Aspergillus flavus* occurs during and after harvest. The aflatoxin produced from *Aspergillus flavus* deteriorates the quality and makes the product unfit for consumption (Sudha et al. 2011). Upon exposure to air, pistachio absorbs moisture rapidly and subsequently resulted in loss in crispiness and changes in its taste (Belitz et al. 2004). Packaging of dried

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product which contains less than 7% moisture content in plastic films of low permeability can be a suitable way for maintaining the quality of the product. Non-permeable materials are used in production and designing flexible films to protect food product against water and oxygen during storage (Paine and Paine 1992; Piringer 2000). The moisture permeability of these packages must be negligible so that product can be stored for several months (Belitz et al. 2004). Escobar et al. (2000) reported that the physico-chemical characteristics of nuts and peanuts were stable for 90 days when cellophane and propylene packages were used (Escobar et al. 2000). Javanshah et al. (2007) reported that packaging pistachio nuts with specially designed 8-layered plastic films under vacuum condition offered effective resistance against oxygen and humidity as well as prevented aflatoxin producer fungi growth even in a highly humid storage condition. No contamination was observed in pistachio nut packed under vacuum condition after 6 months of storage (Javanshah et al. 2007). Even though the best packaging material was discovered, the types of materials that were used for making the aforementioned laminated plastic bags were confidential. On the other hand, Raei et al. (2009) found that packaging of pistachio nut in metalized five-layer films filled with N_2/CO_2 under vacuumed conditions kept the quality of pistachio better and lengthened shelf-life (Raei et al. 2009). Due to the above reasons, it is deemed necessary to find an appropriate packaging material to protect pistachio nut against the surroundings moisture and contamination during high relative humidity storage. Therefore, the objective of this study is to find out the most suitable packaging materials among 5 different types of flexible films which are available in the market.

Materials and methods

The Ohadi cultivar of pistachio nuts was supplied by the Iran Pistachio Research Institute, 77175–435 Rafsanjan, Kerman, Iran. Five types of flexible plastic films (plastic bags) of 200 micron thickness were purchased from the Daroupat Shargh Co., Iran. They include LDPE (Control), food-grade PVC, nylon, PA/PP and PET. The moisture content of pistachio nuts were measured using oven method (AOAC 1990). About 200 g of dried pistachio nuts (4–6% moisture content) were placed in the different types of plastic bags and were sealed using Folienschwei Bgerat machine (model FS77, Germany). Samples were kept at ambient temperature (22–28 °C) and relative humidity of 85–100% for a period of 10 months. Moisture content and aflatoxin level during storage were analysed at every two month intervals i.e. 0, 2, 4, 6, 8 and 10 months.

The total aflatoxin (B_1 , B_2 , G_1 and G_2) was determined by using the AOAC method (999.07) which consists of the immune affinity cleanup (IAC) and High Performance Liquid Chromatography (HPLC) with fluorescence detection and Kobra cell. The moisture content of pistachio samples were measured using drying oven (AOAC 1990).

Statistical analysis

All treatments were carried out in triplicate. All the data were analyzed using the complex randomized design. Comparison between means were done using Duncan test (SAS version 9.2).

Table 1 Changes in moisture content and total aflatoxin level of packaged pistachio nut during storage (22–28 °C)

Attribute	Packaging material	Storage time (month)				
		2	4	6	8	10
Moisture content (%)	LDPE (Control)	8.1 m*	11.0 h	14.2c	17.5 b	20.3 a
	Nylon	6.6 o	8.2 lm	10.0 j	11.4 fg	13.0 d
	PA/PP	6.4 op	7.7 n	9.0 k	10.4 i	11.6 ef
	PET	6.2 p	7.4 n	8.5 l	9.7 j	11.1 gh
	PVC	6.4 op	7.7 n	9.1 k	10.5 i	11.8 e
Total aflatoxin level (ppb)	LDPE (Control)	10.1**	18.2	25.9	300	1019.3
	Nylon	4.1	7.0	18.5	58.8	142.3
	PA/PP	1.8	4.9	16.0	35.0	106.0
	PET	1.3	4.0	12.2	25.0	97.6
	PVC	3.9	8.0	23.2	51.0	122.6

*Different letters within the same columns show significant different ($p \leq 0.05$) among the treatments

**Cut of point for the permitted maximum level of aflatoxin is 10 ppb; LDPE Low density polyethylene, PA/PP Polyamide/Poly propylene, PET Poly ethylene trephthalat, PVC Polyvinyl chloride; Initial moisture content: 5.1% and initial aflatoxin level: not detected; each observation is a mean of three replicates

Results and discussion

Table 1 shows the moisture content of pistachio nut during storage at ambient temperature. The highest moisture content was seen in pistachios packaged in LDPE (Control). Moisture content of pistachio in PET (11.1%) was lower than other packages during the 10th month of storage followed by PA/PP, PVC, nylon and LDPE.

Table 1 shows the aflatoxin level of pistachio nut during storage at 22–28 °C and 85–100% relative humidity. Similar increase in aflatoxin level indicated that these conditions are desirable to fungi growth. Therefore, types of packaging materials used for packaging pistachio nut are important. According to the European Food Safety Authority (2009), the permitted maximum level of total aflatoxin for ready-to-eat pistachio nuts is 10 ppb (EU 2009). In the current study, this value was used as the cut-off point. It was found that PET prevented or inhibited growth of fungi. This finding indicated that the most suitable packaging material for pistachio nut is PET which can extend the shelf life up to 5–6 months at high relative humidity at ambient temperature. The other materials which were PVC, PA/PP and nylon extended the shelf-life up to 4, 4 and 4 months, respectively. These observations indicated that there was a concurrent increase in aflatoxin level as the moisture content of pistachio was increased. It is noticeable that in the presence of moisture, there is a great possibility for other fungi to grow as observed in PA/PP and PVC packages (Arrus et al. 2005). However, after 4 months of onwards both packages contained similar moisture content. On the other hand, the aflatoxin levels in PA/PP and PVC had increased from 4.9, 16.0 and 35.0 ppb to 8.0, 23.2 and 51.0 ppb, respectively. It had been reported that among other types of packaging materials, cellophane films was unsuitable for packaging pistachio due to their high moisture permeability, high cost of production, low sealing ability and low strength (Sajilata et al. 2007). Even though aluminum packages are desirable for packaging pistachio nut, their low thickness and strength could not prevent deformation as a result of vacuum pressure during storage and transportation. Furthermore, the use of these types of packaging material is limited because of high costs and the packages could not withstand the weight of the product.

Based on the lowest concentration of total aflatoxin and moisture absorption level, it was found that PET is the most suitable packaging material for pistachio packaging. This finding is in agreement with Zolfaghariéh (2004) who reported that PET was superior to other packaging materials in terms of sealing qualities, tensile strength, keeping products fresh and puncture resistance (Zolfaghariéh 2004).

Conclusion

Flexible plastic packaging materials can be used effectively for packaging of pistachio nut at high relative humidity condition (85–100%) and 22–25 °C. Considering the moisture absorption and aflatoxin level, the acceptable storage time of pistachio nut in plastic films including LDPE, food-grade PVC, nylon, PA/PP and PET were about 4, 4, 4 and 5–6 months, respectively. Based on this study, the recommended packaging material for packaging of pistachio nuts is PET.

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