EFFECT OF PACKAGING MATERIALS AND STORAGE CONDITIONS ON THE MOISTURE SORPTION ISOTHERM OF SOLAR DRIED TABLE EGG POWDER

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Abstract

Moisture sorption isotherms of solar dried whole egg, egg white and egg yolk stored in different packaging materials at 25°C and relative humidity (RH) range from 22.50 to 92.50%were investigated. The water vapour transmission rate (WVTR) of the packaging materials was also determined at the same storage conditions. The data showed an increase in the (WVTR) values along with increasing the RH levels. The values were slightly high for the LDPE, whereas, there was no marked difference in the WVTR values for both HDPE and laminated polyethylene / nylon bags. The equilibrium moisture content (EMC) values for all samples were slightly high in the egg white, followed by whole egg and egg yolk. The (EMC) values for the samples increased with increasing the storage relative humidity. However, an inverse relationship was observed between the storage relative humidity and the time required to reach equilibration for all samples. The isotherm curves had sigmoidal shapes typical for food and all curves followed similar patterns. The data also showed that the appropriate RH for storage of solar dried egg samples under the previous storage conditions should be below 33% using suitable packaging materials with low water vapour transmission rate such as HDPE or laminated polyethylene / nylon bags.

Key words: Packaging materials, table egg, sorption isotherm, storage

INTRODUCTION

Moisture sorption isotherms of foodstuffs are extremely important. It can be used for modelling the drying process, designing and optimization of drying equipment, ingredient mixing and formulation of foods, predicting shelf-life stability, in addition to determining moisture changes which may occur during storage and selecting appropriate packaging material that optimize or maximize retention of aroma, colour, texture, nutrients and biological stability. Therefore, it is extremely important to know the sorption characteristics of various dried materials [16], [31], [8], [24], [9], [2], [27], [34].

Moisture sorption isotherms describe the relationship between the equilibrium moisture content of foods and the water activity at constant temperatures and pressures [16], [11], [30], [13].

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Equilibrium moisture is a thermodynamic entity and has practical significance in both drying and storage of foods. It is affected by both relative humidity and temperature of the surroundings [29], [33], [18], [26], [28].

Dried eggs are widely used in food preparations because of their microbiological safety and reduced volume with respect to un-shelled or liquid eggs. Moreover, the appeal of dried eggs is their conveniently and long shelf-life. In fact, this product is usually stored without particular care. However, the quality of raw material, processing and storage conditions, strongly influence the quality and safety of egg powder [7], [12], [19].

The fundamental objective of this investigation was to study the effect of packaging materials (LDPE, HDPE and laminated polyethylene / nylon bags) and storage conditions (25°C and relative humidity levels from 22.50 to 92.50% on the moisture sorption isotherm characteristics of solar dried whole egg, egg white and egg yolk.

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MATERIAL AND METHODS

Freshly laid table eggs (two days intervals) were purchased from a local poultry farm (Minia, Egypt) and were used for the study. The eggs were cleaned, manually broken and separated as whole egg, egg white and egg yolk then gently whipped for 3 minutes to provide homogeneous mixtures. The mixtures were spread in a single layer on the drying trays (about 6-8 mm thickness) and dried at 48 ± 2ºC using a mixed-mode forced convection solar dryer. The air velocity was kept constant at 1.9 - 2.4 m/s. The dried samples were ground separately in an electric laboratory mill and sifted through a 60 mesh screen to obtain fine powders [34], [19]. Three different packaging materials were used, 2 mil commercial low density polyethylene (LDPE) bags, 2 mil high density polyethylene (HDPE) bags, from Packaging Concepts and Design, a division of Bader Bag Co., Madison Heights, MN., USA., and 3 mil laminated polyethylene / nylon bags from Cryovac Co., USA. (1 mil = 0.001 inch).

Determination of water vapour transmission rate (WVTR): The WVTR of the test packaging materials (LDPE, HDPE and laminated polyethylene / nylon bags) was determined at various storage conditions as described in the method of [5] as follows:

Three bags of the studied packaging materials were used in this study. About 6 g of desiccant was put in each bag, heat-sealed and weighed. The bags were stored at 25°C and relative humidity range from 22.50 to 92.50% and reweighed every two days until they reached a constant weight. At the end of storage period the amount of water vapour absorbed by the desiccant was calculated. The following equation was used to calculate the WVTR:

$$WVTR = W / (A \times t)$$

Where: WVTR = Rate of water vapour transmission in g/m^2.day; W = Weight gain or loss in g.; A = Exposed area of the package material (total area of the two sides of bag) in m^2, and t = Time, during which gain or loss was observed in hours.

Determination of moisture sorption isotherms: Moisture sorption isotherms of the dried materials (whole egg, egg white and egg yolk) were determined according to the static gravimetric method as described by [14], [25], [21]. Seven saturated salt solutions were used to provide relative humidity range from 22.5 to 92.5% at 25°C. The salts used to obtain different relative humidity values at 25°C are given in Table (1). Triplicates of each sample (2–3g) were accurately weighed in each packaging materials, then heat sealed. The bags were placed on a plastic perforated tray in air/humidity tight plastic containers containing the saturated salt solutions, to avoid any contact between the saturated salt solutions and the samples. For equilibration of samples, the closed containers were then maintained in an incubator equipped with temperature control system with the accuracy of ± 1°C to provide the desired constant temperature of 25°C. The weight of each sample was checked using an analytical balance (with the precision of 0.0001g) initially after three days, and then at one day intervals until a constant weight was reached. The equilibrium moisture content of samples was determined by oven drying at 105°C for overnight and reported as g water/100g sample.

Table 1 Relative humidity values of the saturated salt solutions at 25°C

Salts	CH_3COOK	$MgCl_2$	K_2CO_3	NaBr	NaCl	KCl	Na_2SO_4
RH %	22.50	33.00	43.00	57.70	75.30	84.30	92.50

RESULTS AND DISCUSSIONS

Water vapour transmission rate of packaging materials: The water vapour transmission rate (WVTR) for the studied packaging materials (LDPE, HDPE and laminated polyethylene / nylon bags) under storage conditions of 25°C and relative humidity (RH) levels ranging from 22.50 to 92.50% are presented in Table 2. The results showed that the WVTR values were slightly high in LDPE, whereas, there was no big difference in the WVTR values for both

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HDPE and laminated polyethylene / nylon bags. It could also be seen that, the WVTR values increased with increasing the RH levels. Similar results have been reported by [34] for the LDPE bags.

Table 2 Water vapour transmission rate values (g/m². day)* of the packaging materials at 25°C and different levels of RH.

RH (%)	packaging materials		
	LDPE	HDPE	Laminated PE / nylon
22.50	1.25 ± 0.13	0.21 ± 0.06	0.17 ± 0.06
33.00	1.89 ± 0.10	0.36 ± 0.09	0.32 ± 0.08
43.00	2.05 ± 0.10	0.87 ± 0.09	0.82 ± 0.08
57.70	2.82 ± 0.09	1.06 ± 0.07	1.01 ± 0.04
75.30	3.06 ± 0.07	1.66 ± 0.06	1.61 ± 0.06
84.30	3.20 ± 0.16	2.13 ± 0.07	2.06 ± 0.03
92.50	3.95 ± 0.12	2.35 ± 0.11	2.29 ± 0.10

* Means of three determinations ± SD.

Moisture sorption isotherm of solar dried egg samples: Determination of the sorption isotherms is an indispensable stage in the study of drying of every product. It gives precious information about the hygroscopic equilibrium of the product and allows us to know the domain of stability of the products after drying [6].

If the storage environment has a partial pressure of water vapour above or below the vapour pressure of water at the foodstuff surface, water is adsorbed or desorbed, respectively until it comes into equilibrium with that atmosphere. Exposure to that atmosphere beyond that point will cause no further change in the moisture content of the material [32], [22], [3], [4].

Moisture sorption isotherms of the solar dried egg powders (whole egg, egg white and egg yolk) at 25°C and relative humidity levels from 22.50 to 92.50% are given in Tables (3 – 5). A comparison of the initial moisture content (IMC) with the final equilibrium moisture content (EMC) gives a measure of the capacity for a sample to adsorb or desorbs moisture at different relative humidity values.

Table 3 Effect of packaging materials and storage condition on the equilibrium moisture content and the equilibration time of solar dried whole egg powder

Samples		Parameters *	Relative humidity (%) at 25°C						
			22.50	33.00	43.00	57.70	75.30	84.30	92.50
Whole egg	Without packaging	IMC (%)	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03
		EMC (%)	5.41±0.06	5.72±0.04	8.84±0.05	10.67±0.08	11.61±0.05	13.36±0.07	15.23±0.05
		Time (day)	52	51	45	40	39	37	35
	LDPE	IMC (%)	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03
		EMC (%)	4.59±0.05	4.85±0.03	8.68±0.03	10.50±0.06	11.48±0.05	12.19±0.06	14.46±0.07
		Time (day)	57	56	49	44	43	42	40
	HDPE	IMC (%)	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03
		EMC (%)	4.23±0.02	4.47±0.03	8.11±0.02	10.02±0.04	10.41±0.04	11.94±0.03	13.86±0.07
		Time (day)	60	59	52	47	46	44	43
	Laminated PE / nylon	IMC (%)	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03	2.74±0.03
		EMC (%)	4.19±0.02	4.33±0.03	8.06±0.03	9.74±0.05	10.35±0.04	11.95±0.05	13.70±0.05
		Time (day)	60	59	52	47	46	44	43

* Means of three determinations ± SD. IMC = Initial moisture content EMC = Equilibrium moisture content

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Table 4 Effect of packaging materials and storage condition on the equilibrium moisture content values and the equilibration time of solar dried egg white powder

Samples		Parameters*	Relative humidity (%) at 25°C						
			22.50	33.00	43.00	57.70	75.30	84.30	92.50
Egg white	Without packaging	IMC (%)	2.13±0.02	2.13±0.02	2.13±0.02	2.13 ± 0.02	2.13 ± 0.02	2.13 ± 0.02	2.13±0.02
		EMC (%)	8.94±0.05	9.11±0.03	15.72±0.05	18.25±0.06	20.04±0.06	26.06±0.08	35.23±0.05
		Time (day)	52	51	45	40	39	37	35
	LDPE	IMC (%)	2.13±0.02	2.13±0.02	2.13±0.02	2.13 ± 0.02	2.13 ± 0.02	2.13 ± 0.02	2.13±0.02
		EMC (%)	8.68±0.04	8.76±0.02	14.33±0.05	16.84±0.05	17.23±0.04	21.99±0.06	25.42±0.07
		Time (day)	57	56	49	44	43	42	40
	HDPE	IMC (%)	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02
		EMC (%)	8.17±0.02	8.36±0.03	13.57±0.05	15.63±0.03	16.47±0.03	17.01±0.04	20.24±0.05
		Time (day)	60	59	52	47	46	44	43
	Laminated PE / nylon	IMC (%)	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02	2.13±0.02
		EMC (%)	8.08±0.03	8.27±0.03	13.05±0.07	14.75±0.03	15.41±0.03	16.72±0.05	19.13±0.04
		Time (day)	60	59	52	47	46	44	43

* Means of three determinations ± SD. IMC = Initial moisture content. EMC = Equilibrium moisture content

Table 5 Effect of packaging materials and storage condition on the equilibrium moisture content values and the equilibration time of solar dried egg yolk powder

Samples		Parameters*	Relative humidity (%) at 25°C						
			22.50	33.00	43.00	57.70	75.30	84.30	92.50
Egg yolk	Without packaging	IMC (%)	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02
		EMC (%)	3.32±0.01	3.96±0.01	6.62±0.03	8.71±0.04	9.27±0.03	12.16±0.04	13.63±0.04
		Time (day)	52	51	45	40	39	37	35
	LDPE	IMC (%)	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02
		EMC (%)	2.95±0.04	3.18±0.02	5.88±0.03	6.83±0.04	8.65±0.04	11.41±0.04	13.11±0.04
		Time (day)	57	56	49	44	43	42	40
	HDPE	IMC (%)	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02
		EMC (%)	2.61±0.02	2.92±0.03	5.03±0.03	6.47±0.02	8.07±0.03	9.93 ± 0.05	11.79±0.03
		Time (day)	60	59	52	47	46	44	43
	Laminated PE / nylon	IMC (%)	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02	2.07±0.02
		EMC (%)	2.55±0.03	2.81±0.02	4.94±0.02	6.13±0.02	8.06±0.02	9.35 ± 0.03	11.13±0.04
		Time (day)	60	59	52	47	46	44	43

* Means of three determinations ± SD. IMC = Initial moisture content. EMC = Equilibrium moisture con

The results showed that, at a constant temperature, the EMC values of the samples increased with increasing the storage relative humidity (RH) levels. This might be due to the fact that vapour pressure of water present in foods increases with that of the surrounding atmosphere.

The EMC values were slightly high in the egg white, followed by whole egg and egg yolk for all samples. On the other hand, the unpackaged samples had the highest EMC values (5.41 – 15.23, 8.94 – 35.23 and 3.32 – 13.63%), followed by the samples packaged in the LDPE (4.59 – 14.46, 8.68 – 25.42 and 2.95 – 13.11%) for whole egg, egg white and egg yolk at RH values from 22.50 to 92.50%, respectively. Whereas, there was no marked difference in the EMC values for samples packaged in HDPE and laminated polyethylene / nylon bags as shown in Tables (3 – 5).

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Tables (3 – 5) illustrated the equilibration time for the solar dried whole egg, egg white and egg yolk with different packaging materials. From which it could be seen that, the HDPE and Laminated PE / nylon packaged samples required almost the same time for equilibration at any RH values. It ranged from 43 to 60 days depending on the storage relative humidity. Whereas, the unpackaged samples required short time (35 to 52 days) for equilibration at any relative humidity, followed by the samples packaged in LDPE (40 to 57 days). However, an inverse relationship was observed between the storage relative humidity and the time required to reach equilibration for all samples.

The isotherm curves (Figs. 1 - 4), illustrate the development of the product equilibrium moisture content as a function of the relative humidity of the air surrounding the product. The curves had sigmoidal shapes typical for food and all of these curves followed similar patterns.

Similar results have been reported for different food materials [6], [10], [15], [20], [33], [18], [26], [23], [17], [1], [34].

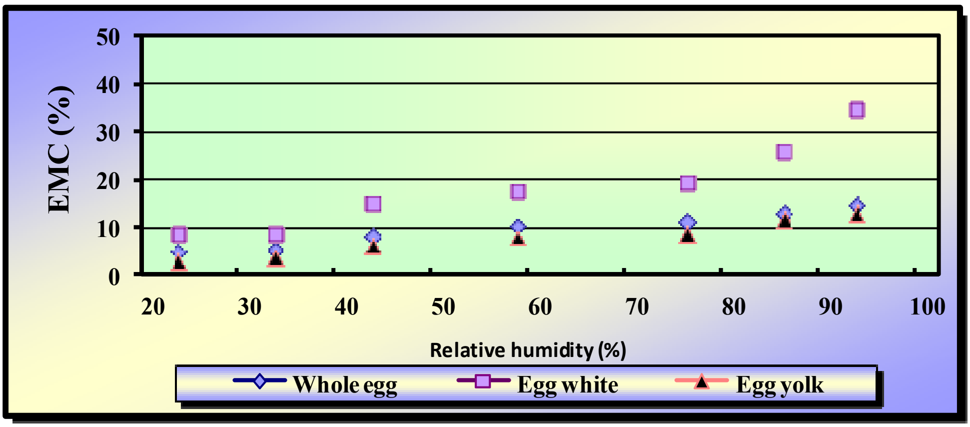

Fig. 1 Sorption isotherm curves of unpackaged solar dried egg powder

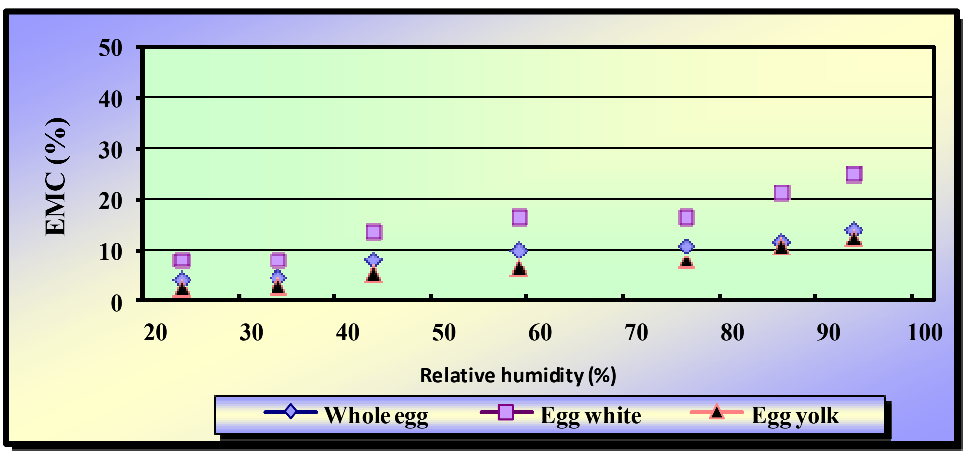

Fig. 2 Sorption isotherm curves of LDPE packaged solar dried egg powder

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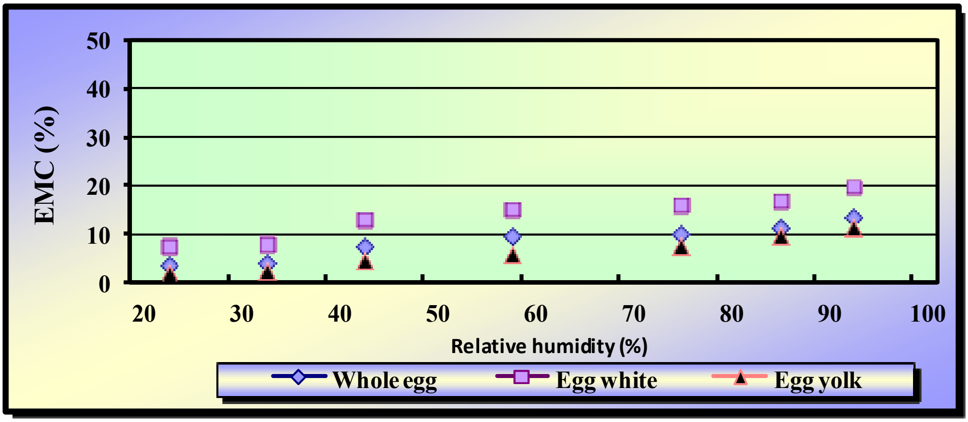

Fig. 3 Sorption isotherm curves of HDPE packaged solar dried egg powder

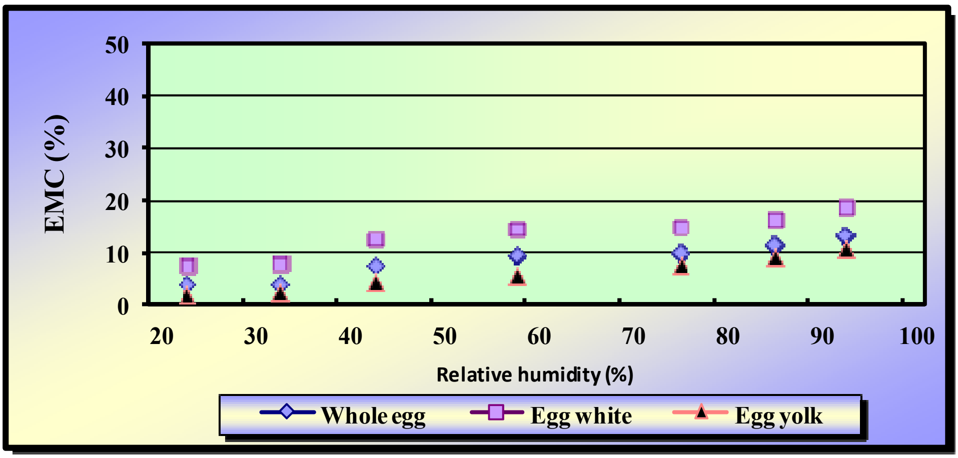

Fig. 4 Sorption isotherm curves of in Laminated PE / nylon packaged solar dried egg powder

CONCLUSIONS

From the obtained results it could be concluded that, the appropriate relative humidity for storage of the solar dried egg samples under the previous storage conditions should be below 33% (at which, the food material has reached to the equilibrium with its surrounding atmosphere), using suitable packaging materials with low water vapour transmission rate such as HDPE or laminated polyethylene / nylon bags.

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