DRYING KINETICS, FUNCTIONAL PROPERTIES AND QUALITY ATTRIBUTES OF SOLAR DRIED TABLE EGGS

M.A. Kenawi[1*], M.M. Zaghloul[1], M. Abd El-Hameed Sanaa[1]

[1]*Minia University, Minia, Egypt*

Abstract

Drying kinetics, functional properties and quality attributes of (whole egg, egg white and egg yolk) were investigatedby using a mixed-mode forced convection solar dryer .The results showed that, the moisture content decreased continuously with drying time. The drying rates were higher at the beginning, then decreased later with decreasing moisture content and increasing drying time. The drying time required to reduce the moisture contents from the initial moisture contents of 73.48, 88.21 and 50.37% to final moisture contents of 2.74, 2.13 and 2.07% was 4, 3 and 5 hours for the whole egg, egg white and egg yolk, respectively. The results also showed a slight decrease in protein, fat and ash contents. On the other hand, there was no remarkable changes observed in the pH values for the dried samples compared with the fresh ones. The quality attributes of solar dried eggs were as good as that of the fresh ones. Solar drying revealed optimum color values and good functional properties. In the light of the obtained results, it could be concluded that solar drying had no remarkable changes on either nutritious qualities or functional properties for the final products. Therefore, it can be used to produce whole egg, egg white and egg yolk in powder forms without adversely affecting their quality attributes, nutritional and functional properties.

Key words: Table eggs, solar drying, functional properties, quality attributes

INTRODUCTION

Eggs are highly nutritious as well as low cost protein source. Egg proteins are extensively utilized in many food products due to their unique functional properties. However, the egg is a highly perishable food product, which could lose its quality rapidly during the period between collection and consumption [39], [21], [35] and [6]. Recently, there has been an increased demand for dried egg products in the food industry for ready-to-use products and handling considerations. Spray-drying is one of the techniques frequently used to obtain powdered eggs from liquid eggs [13] and [3]. Dried eggs are widely used in food preparations because of their microbiological safety and their reduced volume with respect to un-shelled or liquid eggs [5]. 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 [11]. The high energy consumption of drying operation, sharp rise in energy costs and importance of environmental protection have directed interest towards the application of solar energy to agricultural and industrial processes. Solar energy is preferred because it is natural, free, abundant, renewable, inexhaustible and non-polluting. It can be tapped at relatively low cost and has no associated environmental dangers. Therefore, using solar energy can considerably reduce energy costs [4], [25], [26] and [37]. Knowledge of drying kinetics is important in the design, simulation and optimization of drying processes. It is affected by drying conditions, types of dryer and characteristics of materials to be dried. The drying curve will give information on the time necessary for a product to be dried under certain conditions [14], [33], [30] and [12]. Functional properties denote those physico-chemical properties of food proteins that determine their behavior in foods during

*Corresponding author:
mohamedkenawi@ymail.com
The manuscript was received: 17.12.2014
Accepted for publication: 20.01.2015

processing, storage, preparation and consumption. These properties and the manner in which proteins interact with other components, directly and indirectly affect processing applications, food quality and ultimately acceptance. The type of functional property required in a protein or a protein mix varies with the particular food system in question [18].

The fundamental objectives of this investigation were to study the drying kinetics, functional properties and quality attributes of whole egg, egg white and egg yolk dried under the solar drying conditions.

MATERIAL AND METHODS

Preparation of fresh materials for drying process: Freshly laid eggs (two-days-old) were purchased from a local poultry farm (Minia, Egypt). 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 [41]. The dried samples were ground separately in an electric laboratory mill and sifted through a 60 mesh screen to obtain fine powders. The powders were packed in polyethylene bags and stored in airtight containers for analysis and use.

Drying kinetics: Drying curves were obtained by periodic determination of weight and moisture content of samples. The weight loss from the samples was recorded at certain intervals using an electronic balance with least count of 0.1g. Drying was continued till the sample attained the desired moisture level (equilibrium moisture content). The instantaneous moisture contents at any given time were computed according to [9] using the following equation:

$$M_{twb} = 1 - \left[\frac{(1 - M_{owb})\, W_o}{W_t}\right]$$

Where: M_{twb} = moisture content at time, t (decimal, wet basis); M_{owb} = initial moisture content (decimal, wet basis); W_o = initial weight of fresh product (kg); W_t = weight of product at time, t (kg) and Percentage $M_{twb} = M_{twb}$ x 100.

Drying ratio: Drying ratio of the dried materials was calculated according to [38] as follows:

Drying ratio = weight of the fresh material / weight of the dried material

Chemical analysis: Moisture, crude protein, crude fat and ash contents were determined according to the methods of [27]. Carbohydrates were calculated by difference. All determinations were performed in triplicates and the means were reported.

Sensory evaluation: Sensory evaluation for the color, flavor, appearance, and overall quality were done in order to determine consumer acceptability. A numerical hedonic scale which ranged from 1 to 10 (1 is very bad and 10 for excellent) was used for sensory evaluation [20].

Determination of color: The color characteristics of samples were measured by a color difference meter (model color Tec-PCM, USA) using different color parameters (L, a, b) according to [10]. In addition, numerical total color difference (ΔE), hue angle and color intensity (chroma) were calculated according to [34].

Functional properties:

Bulk density: A calibrated glass centrifuge tube was accurately weighed and filled up to 5 ml with the powdered sample. The tube was reweighed and from the difference in weights, the bulk density of the sample was calculated and expressed as g/ml [17].

Water absorption capacity and oil absorption capacity: The water absorption capacity and the oil absorption capacity were determined for the dried powdered samples according to the method of [15].

Gelation properties: Gelation properties for the solar dried egg powders were determined according to the methods of [32] and [16].

Emulsification capacity: Emulsification capacity for the dried samples were determined according to the method of [16].

Foaming capacity and Foam stability: The capacity (FC), and foam stability (FS) for the dried egg powders were determined according to the methods of [23] and [16].

RESULTS AND DISCUSSIONS

Drying kinetics of egg samples: The drying curves (moisture content versus drying time) the whole egg, egg white and egg yolk samples under the solar drying conditions are shown in Fig. (1). From which, it could be seen that moisture content decreases continuously with drying time. The drying process was continued until the material achieves its final moisture content at which the moisture content does not decrease substantially with increasing drying time. This final moisture content was considered as the value of equilibrium moisture content [9]and [30]. It is obviously observed from the figure that the moisture content is decreased rapedly at the initial stages of drying and thereafter became slower as drying proceeds. The drying rates were high at the beginning of the process probably due to the evaporation of moisture from the surface of samples and decreased as the moisture content decreased too. The accelerated drying rates may be attributed to internal heat generation [28], [8], and [31]. It is evident from the curves that the drying time required to reduce the moisture contents from the initial moisture contents of 73.48, 88.21 and 50.37% to final moisture contents of 2.74, 2.13 and 2.07% were 4, 3 and 5 hours for the whole egg, egg white and egg yolk, respectively.

The quality attributes of egg samples: The drying ratio, weight and percentage of egg components are presented in Table (1). The data showed that egg white, yolk and shell represent 57.61, 31.85 and 10.54%, respectively as a percentage from the whole egg. The drying ratio values were about 3.67 for whole egg, 8.30 for egg white and 1.97 for egg yolk. The results showed that the drying ratio is dependent on the moisture content of the fresh and dried food materials.

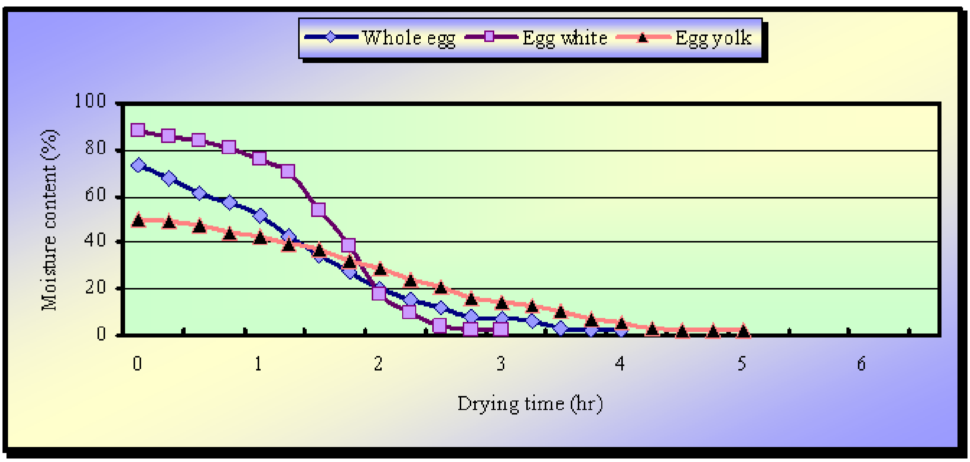

Fig. 1 Drying curves of solar dried egg samples (whole, white and yolk)

Table 1 Drying ratio, weight and percentage of egg components

Parameters*	Egg components			
	Whole	White	Yolk	Shell
Weight (gm)	59 ± 2.50	33.99 ± 1.44	18.79 ± 0.80	6.22 ± 0.26
Percentage of components	100	57.61	31.85	10.54
Drying ratio**	3.67 ± 0.02	8.30 ± 0.03	1.97 ± 0.01	-

*Means of three determinations ± SD. **Weight of fresh material / Weight of dried material

Chemical composition and pH values of fresh and solar dried egg powder: The proximate chemical composition of the fresh and solar dried whole egg, egg white and egg yolk are shown in Table (2). It could be seen that the drying process caused a sharp decrease in moisture content and consequently led to an increase in the dry matter content of all the studied materials. The results showed a slight decrease in protein, fat and ash contents, however, carbohydrates were slightly increased. On the other hand, there was no remarkable changes observed in pH values in the dried samples compared with the fresh ones. In the light of the obtained results, it could be concluded that solar drying had no remarkable changes on the nutritious qualities of the final products. [27] studied the effect of oven drying on the functional and nutritional properties of whole egg and its components. He found that the whole egg, egg yolk, and egg white powders can be produced using the oven drying method, at controlled temperature of 44°C with no adversely effect on their functional and nutritional properties. Hence they could be incorporated as nutritive ingredients in the production of healthy food products.

Sensory characteristics of solar dried egg samples: Sensory evaluation for color, flavor, appearance, and overall quality of the whole egg, egg white and egg yolk samples as affected by the drying process were done in order to determine consumer acceptability. The results are shown in Fig. (2). From which, it could be seen that the sensory quality attributes of the solar dried egg samples were as good as that of fresh ones.

Table 2 Chemical composition and pH values of fresh and solar dried egg samples (dry weight basis)

Constituents (%)*	Whole egg		Egg white		Egg yolk	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
Dry matter	26.52±0.04	97.26±0.05	11.79±0.04	97.87 ± 0.03	49.63 ± 0.06	97.93 ± 0.04
Protein**	48.19±0.07	47.74±0.05	89.17±0.05	88.65 ± 0.05	32.15 ± 0.04	31.72 ± 0.03
Crude fat	44.72±0.04	44.63±0.02	0.06 ± 0.01	0.05 ± 0.01	63.17 ± 0.05	63.03 ± 0.07
Ash	3.66±0.06	3.61 ± 0.05	5.87 ± 0.04	5.81 ± 0.06	3.21 ± 0.03	3.12 ± 0.03
Carbohydrates***	3.43±0.05	4.02 ± 0.04	4.94 ± 0.05	5.49 ± 0.05	1.47 ± 0.05	1.86 ± 0.05
pH values*	7.28±0.06	7.35 ± 0.07	8.04 ± 0.06	8.21 ± 0.08	6.06 ± 0.06	6.36 ± 0.06

* Means of three determinations ± SD. ** T.N. x 6.25. *** Calculated by difference

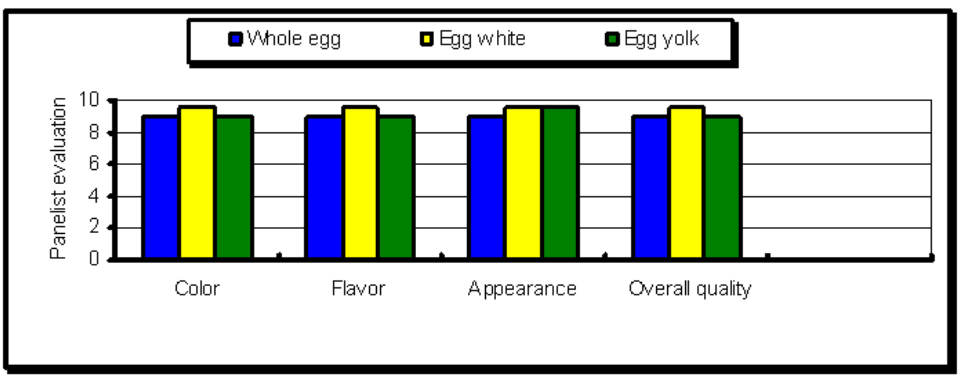

Fig. 2 Sensory characteristics of solar dried egg samples

Color parameters of fresh and solar dried eggs: The results of color parameters (L, a, b, ΔE, hue angle and chroma) for the fresh and solar dried whole egg, egg white and egg yolk are presented in Table (3). The results showed that, a-values and b-values increased for all the dried samples as compared to the fresh ones. L-values followed the same pattern (except for whole egg) as a- and b-values.

It could be seen from the data that the hue angle values were decreased in the case of whole egg and egg yolk as a result of the drying process. However, the values were increased in the case of egg white as compared to the fresh samples. This could be due to the change in the values of both redness (a-value) and yellowness (b-value). Chroma values were increased for all the dried samples as compared to the fresh ones. It was reported that chroma is the indicator of color saturation and intensity. The higher the values, the more desirable they are [22], [1], and [34]. In the light of the obtained results, it could be concluded that solar drying revealed optimum color values.

Table 3 Color parameters of fresh and solar dried egg samples (whole, white and yolk)

Color parameters*	Whole egg		Egg white		Egg yolk	
	Fresh	Dried	Fresh	Dried	Fresh	Dried
L (Lightness)	72.24 ± 1.85	70.50 ± 1.16	73.03±1.63	89.41 ± 1.21	56.56±1.63	76.06 ± 0.47
a (redness/greenness)	2.91 ± 0.15	18.25 ± 0.76	2.35 ± 0.14	5.48 ± 0.26	9.64 ± 1.02	10.79 ± 1.01
b (yellowness/blueness)	25.63 ± 1.32	37.84 ± 0.57	4.05 ± 0.37	11.81 ± 0.02	44.56±1.27	45.73 ± 1.65
ΔE**	00.00	19.68	00.00	18.39	00.00	19.57
Hue angle***	83.52	64.25	59.88	65.11	77.79	76.72
Chroma****	25.79	42.01	4.68	13.02	45.59	46.99

*Means of three determinations ± SD. **$\Delta E = [(L - L_o)^2 + (a - a_o)^2 + (b - b_o)^2]$

*** Hue angle = $[\tan^{-1}(b/a)]$. ****Chroma = $[(a^2 + b^2)$

Functional properties of solar dried egg samples: Functional properties of the solar dried whole egg, egg white and egg yolk are presented in Tables (4 and 5). It could be seen that the solar dried whole egg and egg white had the same values of bulk density (0.44g/ml) which were higher than that of egg yolk (0.38g/ml).

Bulk density is important in determining how much space (volume) the material will occupy when packed [19]. Data in Table (4) revealed that, egg yolk had the highest value of oil absorption capacity (151.78 g oil/100g sample) followed by whole egg (146.90 g oil/100g sample) and egg white (144.63 g oil/100g sample). The results clearly showed an irreversible relationship between bulk density and oil absorption capacity of the studied samples. It is probable that most of the oil held by protein is actually physically entrapped and therefore the amount is influenced mainly by the surface area and bulk density of the protein preparation [7], [36], and [18]. The data also showed that whole egg had the highest water absorption capacity (WAC) value (167.36g water/100g sample). The water absorption capacity for the egg white did not determine because it is highly soluble in water. Table (4) illustrates the emulsification capacity (EC) values for the solar dried egg powders (expressed as ml oil emulsified by 100 ml of 8% w/v sample suspension). The results showed that solar dried egg white had the lowest EC value (145 ml oil) as compared to whole egg (190 ml oil) and egg yolk (200 ml oil). Emulsifying activity (EA) had the same trend of (EC). The highest value was found to be (91.33%) for whole egg followed by egg yolk (90.86%), however, egg white had the lowest value (62.86%). On the other hand, the whole egg had highest value (84.62%) of emulsion stability (ES) compared to the egg yolk (79.17%). The ES for the egg white did not determine due to the partial protein denaturation that might be caused by the heating process at 80°C for 30 minutes during the determination of (ES). [6] reported that heating at temperature higher than 64°C resulted in gelation of the egg proteins and as a result emulsions could not be prepared. It was reported that EA is the ability for a surfactant to form an emulsion under given conditions and is directly related to oil droplet size, the smaller the size the greater the activity. By nature, emulsions are thermodynamically unstable and eventually separate into oil and water phases [29]. Therefore, (ES) is the measure of how slowly an emulsion separates into oil and water phases. Gelation properties (expressed as least gelation concentration, LGC) are necessary to the structure of many foods and are related to the rheological properties of a variety of food system. The results in Table (4) showed that, the minimum concentration percentages required to obtain strong gels were 14.0, 8.0 and 16.0% for whole egg, egg white and egg yolk, respectively. Gelation has evident importance given the amount of available products to consumers, such as desserts, puddings, reformulated meat products, tofu, and surimi [24]. Foaming properties of whole egg, egg white and egg yolk are presented in Table (5). The data showed that egg white had the highest foaming capacity (FC) (expressed as percentage volume increase) value (70%) compared whole egg (62%) or egg yolk (44%). The results also showed that whole egg had the highest foam stability (FS) value (78.57%), whereas whole egg and egg yolk had the values of (77.42% and 72.73%) respectevely.

In the light of the obtained results, it could be concluded that solar drying revealed good functional properties of the final products (whole egg, egg white and egg yolk).

Table 4 Functional properties of solar dried egg samples (whole, white and yolk)

Functional properties*	Solar dried egg samples		
	Whole	White	Yolk
Bulk density (g sample/ml)	0.44 ± 0.01	0.44 ± 0.01	0.38 ± 0.01
Oil absorption capacity (g oil/100g)	146.90 ± 3.45	144.63 ± 3.69	151.78 ± 3.52
Water absorption capacity (g water/100g)**	167.36 ± 2.55	ND	148.71 ± 2.36
Emulsification capacity***	190 ± 5.00	145 ± 5.00	200 ± 5.00
Emulsifying activity (%)	91.33 ± 2.00	62.86 ± 1.43	90.86 ± 2.00
Emulsion stability (%)	84.62 ± 2.00	ND	79.17 ± 2.00
Least gelation concentration (% w/v) ****	14.00	8.00	16.00

* Means of three determinations ± SD. ** Corrected for soluble solids. *** ml oil/100 ml of 8% (w/v) sample suspens *** Concentration at which the sample from inverted test tube did not fall down or slip.

Table 5 Foaming capacity (FC) and foam stability (FS) for solar dried egg samples (whole, white and yolk)

Time of stability (min)	Solar dried egg samples					
	Whole		White		Yolk	
	Volume after whipping (ml)	FC (%)*	Volume after whipping (ml)	FC (%)	Volume after whipping (ml)	FC (%)
0.5	162	62	170	70	144	44
5	160	60	165	65	142	42
10	156	56	165	65	138	38
15	156	56	165	65	138	38
20	156	56	162	62	136	36
25	154	54	162	62	136	36
30	152	52	160	60	134	34
60	148	48	155	55	132	32
90	146	46	150	50	130	30
120	144	44	147	47	130	30
150	144	44	144	44	130	30
180	142	42	142	42	128	28
**FS_{60min}	77.42		78.57		72.73	

* Values are average of three determinations **FS_{60min} = ($FC_{60\ min}$ / FC) × 100

CONCLUSIONS

In the light of the obtained results, it could be concluded that solar drying had no remarkable changes on the nutritious qualities and functional properties of the final products. Hence, it can be used to produce whole egg, egg white and egg yolk in powder forms with good quality attributes nutritional and functional properties

REFERENCES

[1] Albanese, D.; Russo, L.; Cinquanta, L.; Brasiello, A. and Matteo, M.D. (2007): Physical and chemical changes in minimally processed

green asparagus during cold-storage. Food Chem., 101: 274-280.
[2] AOAC (1995): Official methods of analysis,16th ed. Association of Official Analytical Chemists International, Arlington, U.S.A.
[3] Ayadi, M.A.; Khemakhem, M.; Belgith, H. and Attia, H. (2008): Effect of moderate spray drying conditions on functionality of dried egg white and whole egg. J. Food Sci., 73: E281-E287.
[4] Basunia, M.A. and Abe, T. (2001): Thin-layer solar drying characteristics of rough rice under natural convection. J. Food Eng., 47: 295-301.
[5] Bergquist, I.H. (1995): Egg dehydration. In: Stadelman, W.J. and Cotterill, O.J. (eds.), Egg Science and Technology, 4th ed., Pp: 335-76. Binghamton, Food Product Press, NY.
[6] Campbell, L.; Raikos, V. and Euston, S.R. (2005): Heat stability and emulsifying ability of whole egg and egg yolk as related to heat treatment. Food Hydrocolloids, 19: 533-539.
[7] Dench, J.E. (1982): Extraction of nitrogenous material from winged bean (*Psophocarpus tetragonolopus* L.) flour and the preparation and properties of protein isolates. J. Sci. Food Agric., 33: 173-184.
[8] Doymaz, I. (2007): Air-drying characteristics of tomatoes. J. Food Eng., 78: 1291-1297.
[9] Ekechukwu, O.V. (1999): Review of solar-energy drying systems I: an overview of drying principles and theory. Energy Conversion and Management, 40: 593-613.
[10] Francis, F.J. (1983): Colorimetry of foods. In: physical properties of foods (edited by M. Peleg and B.B. Edwards). pp. 105-123. Westport, CT: AVI Publishing.
[11] Galobart, J.; Guardiola, F.; Barroeta, A.C.; Lopez-Ferrer, S. and Baucells, M.D. (2002): Influence of dietary supplementation with α-tocopheryl acetate and canthaxanthin on cholesterol oxidation in ω3 and ω6 fatty acids-enriched spray-dried eggs. J. Food Sci., 67: 2460-2466.
[12] Giri, S.K. and Prasad, S. (2007): Drying kinetics and rehydration characteristics of microwave-vacuum and convective hot-air dried mushrooms. J. Food Eng., 78: 512-521.
[13] Guardiola, F.; Codony, R.; Miskin, D.; Rafecas, M. and Boatella, J. (1995): Oxysterol formation in egg powder and relationship with other quality parameters. J. Agric. Food Chem., 43, 1903-1907.
[14] Heldman, D.R, and Hartel, R.W. (1997): Principles of food processing, Chapman and Hall, Thomson publishing, Florence, KY.
[15] Hulse, J.H.; Rachie, K.O. and Billingsley, L.W. (1977): Nutritional standards and methods of evaluation for food legume breeders. International Development Research Center, Postal Address: Box 8500, Ottawa, Canda, Head Office: 60 Queen street, Ottawa.
[16] Ihekoronye, A.I. (1986): Functional properties of meal products of the Nigerian "Red Skin" groundnut (*Arachis hypogaea* L.). J. Sci. Food Agric., 37: 1035-1041.
[17] Jones, L.J. and Tung, M.A. (1983): Functional properties of modified oil seed protein concentrates and isolates. Can. Inst. Food Sci. Technol. J., 16: 57-62.
[18] Kinsella, J.E.; Damodaran, S. and German, B. (1985): Physico-chemical and functional properties of oil seed protein with emphasis on soy proteins. In: New protein foods, Vol. 5, seed storage protein, Ed. A.M. Altschul and H.L. Wilcke, Academic Press Inc., London, New York, pp. 107-179.
[19] Kramer, A. and Kwee, W.H. (1977): Functional and nutritional properties of tomato protein concentrates. J. Food Sci., 42: 207-211.
[20] Larmond, E. (1977): Laboratory methods for sensory evaluation of food. Canadian Government Publishing Center, Ottawa, Canada.
[21] Mara, L.; Hidalgo, A.; Comelli, E.M. and Rossi, M. (1996): Evaluation of chemical and physical albumen characteristics during the storage of shell eggs. J. Agric. Food Chem., 44:1235-1240.
[22] McGuire, R.G. (1992): Reporting of objective color measurements. HortScience, 27: 1254-1255.
[23] Mc Watters, K.H.; Cherry, J.P. and Holmes, M.R. (1976): Influence of suspension medium and pH on functional and protein properties of defatted peanut meal. J. Agric. Food Chem., 24: 517-523.
[24] Mine, Y. (1995): Recent advances in the understanding of egg white protein functionally. Trends in Food Science and Technology, 6: 225-231.
[25] Mohamed, L.A.; Kouhila, M.; Jamali, A.; Lahsasni, S.; Kechaou, N. and Mahrouz, M. (2005): Single layer solar drying behavior of *Citrus aurantium* leaves under forced convection. Energy Conversion and Management, 46: 1473-1483.
[26] Mwithiga, G. and Kigo, S.N. (2006): Performance of a solar dryer with limited sun tracking capability. J. Food Eng., 74: 247-252.
[27] Ndife, J.; Udobi; Ejikeme, C. and Amaechi, N. (2010): Effect of oven drying on the functional and nutritional properties of whole egg and its components. African Journal of Food Science, 4: 254-257.
[28] Pathare, P.B. and Sharma, G.P. (2006): Effective moisture diffusivity of onion slices undergoing infrared convective drying. Biosystems Eng., 93: 285-291.
[29] Pearce, K.N. and Kinsella, J.E. (1978): Emulsifying properties of proteins: evaluation of a

turbidimetric technique. J. Agric. Food Chem., 26: 716-723.
[30] Ramaswamy, H. and Marcotte, M. (2006). Food processing, principles and applications, CRC press, Taylor & Francis Group, Boca Raton.
[31] Sarsavadia, P.N. (2007): Development of a solar-assisted dryer and evaluation of energy requirement for the drying of onion. Renewable Energy, 32: 2529-2547.
[32] Sathe, S.K.; Deshpande, S.S. and Salunkhe, D.K. (1982): Functional properties of lupin seeds (*Lupinus mutabilis*) protein and proein concentrates. J. Food Sci., 47: 491-497.
[33] Senadeera, W.; Bhandari, B.R.; Young, G. and Wijesinghe, B. (2003): Influence of shapes of selected vegetable materials on drying kinetics during fluidized bed drying. J. Food Eng., 58: 277-283.
[34] Shih, M.C.; Kuo, C.C. and Chiang, W. (2009): Effects of drying and extrusion on color, chemical composition, antioxidant activities and mitogenic response of spleen lymphocytes of sweet potatoes. Food Chem., 117: 114-121.
[35] Surai, P.F. and Sparks, N.H.C. (2001): Designer egg: From improvement of egg composition to functional food. Trends in Food Sci. Technol., 12: 7-16.
[36] Tasneem, R.; Ramamam, S. and Subramanian, N. (1982): Functional properties of guar seed meal detoxified by different methods. J. Food Sci., 47: 1323-1328.
[37] Tripathy, P.P. and Kumar, S. (2009): A methodology for determination of temperature dependent mass transfer coefficients from drying kinetics: Application to solar drying. J. Food Eng., 90: 212-218.
[38] Van-Arsdel, W.B.; Copley, M.G. and Morgan, A.I. (1973): " Food dehydration" Vol. 11. 2nd Ed. Practices and applications. AVI publishing Co., IVC, Westport, Conn., USA.
[39] Watkins, B.A. (1995): The nutritive value of the egg. In Stadelman, W.J. and Cotterill, O.J. (eds.), Egg Science and Technology, 4th ed., Pp: 177-194. Food Product Press, Binghamton, NY.
[40] Yasumatsu, K.; Sawada, K.; Moritaka, S.; Misaki, M., Toda, J.; Wada, T., and Ishii, K. (1972): Whipping and emulsifying properties of soybean products. Agricultural Biological Chemistry, 36: 719-727.
[41] Zaghloul, M.M.; Kenawi, M.A.; Iskander, M.H. and Sanaa M.A. (2012): Using the solar energy in developing a mixed-mode forced convection solar dryer and its application on some food materials. Minia International Conference for Agriculture and Irrigation in the Nile Basin Countries, 26th -29th March 2012, El-Minia, Egypt. 691-702.