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Comparative study of fatty-acid composition of table eggs from the Jeddah food market and effect of value addition in omega-3 biofortified eggs.

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Health consciousness has increased the desire of people around the world to consume functional foods. Omega-3 essential fatty acids are one amongst these beneficial and important health supplements without which a general predisposition to degenerative and stress related disorders can occur. Saudi Arabia has shown an alarming increase in obesity (Al-Nozha, Al-Mazrou et al., 2005), diabetes (Alqurashi, Aljabri et al., 2011), and cardiovascular disease (Al-Nozha, Arafah et al., 2004) in the last few decades mainly due to nutritional transitions and lifestyle alterations (Amuna & Zotor, 2008). Lack of nutrient dense foods and the prevailing food related disorder of obesity (Popkin, 2001; Prentice, 2014) especially render egg as a choice food to be value-added for attaining nutritional security in Saudi Arabia and in effect reverse the increasing incidences of lifestyle diseases. Nutritional intervention through a commonly consumed food product would be an important step in improving the health of the people, and reducing health care costs. As eggs are a frequently consumed food item in Saudi Arabia, enriching them with omega-3 fatty acids would be an excellent way to alleviate the existing problems. A significant deposition of omega-3 fatty acids in the eggs was observed when the diet of hens was supplemented with omega-3 fatty acids from either flaxseed or fish oil source. Inadequacy of omega-3 fatty acids could thus be rectified by producing omega-3 enriched eggs from chicken supplemented with flaxseed or fish oil source, and thus contribute towards better health choice to the consumer.

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1. Introduction

Lifestyle diseases arising from nutritional deficiencies are taking alarming proportions in Saudi Arabia. Excesses in the composition of fat are evident from the ever-growing junk food consumption in the Saudi Arabia. Increased consumption of omega-6 type of fats as in the diets in the western countries (Simopoulos, 2002; Massiera, et al., 2010) is causing an imbalance in the recommended omega-6: omega -3 fatty acid ratio (Ferrier, et al., 1995). The American Heart Association (AHA) guideline recommends food practices that have a positive association with good health and do not disallow or limit egg consumption (Kritchevsky, 2004). Health professionals recommend a lowering of high cholesterol and increasing consumption of polyunsaturated fatty acids for better health outcomes.

Past four decades have seen drastic changes in the socio-economic conditions in Saudi Arabia. The beneficial effects of these changes have, however, unfortunately been paralleled by negative influences on the nutrition, and lifestyle of Saudi population resulting in adverse health conditions. A dietary shift from the high fiber and low fat diet of the past to the unhealthy diets in today's times has resulted in increased risk for cardiovascular problems, diabetes, and obesity (Musaiger, 2002). According to the Bahrain Medical Bulletin (2000) strategies to prevent obesity in Saudi Arabia should include encouragement of outdoor physical exercise, decreased consumption of fatty foods, and lifestyle changes. Saudi Arabia has a high percentage of adults suffering from high cholesterol (Baba, 2000). High energy foods rich in fats and sugars (Musaiger, 2002, 1994) have increased the benchmark of total energy consumption per capita to 3000 Kcal. Saudi recommendations allow energy intakes of 2100 Kcal per capita (Khan & Al-Kanhal, 1998). Economic affluence has resulted in sedentary habits leading to fat consumption beyond the 30% of the allowed energy intake recommended for sedentary individuals (FAO, 1994). Therefore, there is an increased need for functional foods providing health benefits to the general population. Furthermore, increased health awareness has created recognition for products enhancing good health and healthy nutrition has increased consumer demand for healthy food products.

Omega-3 fatty acids are one of the most sought after components in the functional food sector. It has been observed (Ramirez, Amate et al., 2001) that egg lipids are efficiently absorbed in the body, thereby increasing the bioavailability of docosa hexaenoic acid (DHA) and also increasing levels of high density lipoproteins (HDL). This makes the omega-3 enriched egg a potentially

health benefitting functional food (Lewis, et al., 2000; Gil, et al., 2003; Hoffman, et al., 2004; Yalcin & Unal, 2010). Eggs have been well accepted as a safe and nutritious food for all ages. Recommendations from the Canadian government requires 0.5 % of total energy intake as omega-3 fatty acid based on the fact that North American diets are low in this nutrient (Canada Health Recommendation 1990). This has prompted the egg industry to step in to bring back omega-3 fatty acids into the food chain. Omega-3 enriched eggs would, therefore, serve as an ideal food to increase the amount of omega-3 fatty acids in the Saudi Arabian diet. Egg is a balanced and nutrient rich inexpensive food containing high bioavailable protein, making it a reference food for protein quality (Herron & Fernandez, 2004). The Saudi poultry industry centers around two major products i.e. table eggs and broiler meat. Production of eggs has increased from 145 to 191 thousand tons from the year 2005 to 2009. Food Agriculture Organization figures of import for the major Arab countries during the years 200-2005 showed a 66% increase, ranging from 465,000 to 770,000 tons, in a short period of 5 years. Production of table eggs has been estimated to increase by around 50% owing to population boom by around 25% and enhancement in per capita consumption of eggs [Musa et al., 2008]. The awareness that the saturated fats and cholesterol are bad for health has turned away many consumers from meat and eggs and this is the main reason that is limiting popularization of poultry products in spite of immense nutritive values.

One of the most intriguing developments related to the food industry and public health in future may come from a higher demand of the essential omega-3 fatty acids, such as alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA) in the food products. Traditionally, most of the omega-3 fatty acids in the diet have come from fish and fish oil but such foods are not eaten in enough quantities or the right kind of omega-3 rich fish are not consumed. In an effort to meet the growing demands of the health conscious consumers, egg as a nutrient dense food has been tapped (Drewnowski, 2005). The egg could serve as an unadulterated rich source of omega-3 fatty acid. Eggs contain a high density of nutrients and are a good source of proteins, vitamins, and lipids of high quality such as phospholipids and polyunsaturated fatty acids PUFAs (Meluzzi, et al., 2000; Ruxton, 2010) . In olden days, the country eggs contained a fairly good amount of omega-3 fatty acids and were healthy and safe for consumption. The present day poultry eggs are depleted of this essential nutrient because of intensive and industrialized poultry

farming. Moreover, the health conscious consumer is dissuaded from consuming eggs because of its high fat content (Hu, et al., 1999; Qureshi, et al., 2007, Yafee et al., 1991).

The fatty acid composition of yolk lipids can be altered depending upon the diet of the layer birds (Ahmad et al 2009, Singh et al; 2010). These omega-3 enriched eggs contain almost four fold DHA than the normal amount in commercially sold eggs (Lewis, Seburg et al., 2000). Eggs produced from hens receiving conventional feeds tend to be relatively high in omega-6 fatty acids but poultry feed manipulation can be used successfully to either increase the amount of DHA directly using fish oil or indirectly by increasing the levels of precursor ALA by feeding flaxseed(Jiang & Sim, 1993; Milinsk, et al., 2003, Sparks et al .,2006).

Eggs enriched with omega -3 fatty acids could contribute to the dietary intake of omega – 3 PUFAs and could be an alternative source of omega -3 fatty acids which is derived normally from fish. Flaxseed in poultry feed for hens may prove to be a key food ingredient in establishing egg consumption for promoting better heart health in humans (Mary et al., 1997).

The objective of present study was to evaluate and compare Omega-3 fatty acid content in commercially sold eggs in Jeddah market and the eggs bio-fortified using omega-3 fatty acid sources, flaxseed and fish sources, in poultry diet. The aims of the experiment were to 1) study the levels of omega-3 fatty acids in the commercially sold eggs in Jeddah market to find out the need for compositional alterations of these fatty acids for egg production, 2) to select a suitable omega-3 poultry feed source for the production of omega-3 bio-fortified-eggs that would help us in establishing economic feasibility for large scale production, and 3) to establish the levels of omega-3 fatty acids required to be incorporated into the commercially available eggs, to bring back omega-3 fatty acids into the already existing food chain.

2. Materials and methods

2.1. Procurement of eggs

Commercial hen eggs were obtained fresh from well reputed departmental stores located at different places in Jeddah. For Omega-3 fortification of eggs– thirty six commercial strain hens aged 21 weeks were used for a period of 4 wks (21 wk – 25 wks age). The hens were randomly divided into three dietary treatment groups (n=12 per group). The hens were housed individually in 60 inches floor space per hen and under similar management, light, and housing conditions.

The feed differed in all the treatment groups. Feeding of crushed Flax seed or fish oil and egg collection was conducted daily during the morning hours and eggs were stored at 4°C for further experimentation.

2.2. Egg analysis

Eggs from 4th day of production each week were weighed and subsequently taken for analysis. Whole egg was separated using a separator and weights of yolk and albumin recorded.

2.3 Diet

Diets were kept refrigerated till use daily. The birds were divided into following three dietary treatment groups:

1] Control group were fed the control diet (Layeration 18 Meal, containing Crude protein 18%, crude fat 3.50 %, crude fiber 3.50%, Ash 13.50%, salt 0.40%, calcium 3.80%, phosphorus 0.60%, Vitamin A 10.00 IU/g, Vitamin D 3.00 IU/g, Vitamin E 10.00 IU/kg, Energy, ME Kcal/Kg 2750). Trace minerals added include copper, manganese, iron, iodine, selenium, and zinc. Mainly the control diet contained corn (approx 70%) soya bean extract (approx 20%), and broken wheat, oats and millet in percentages of 2-5.

2) Flaxseed diet group were fed the control diet + 8% crushed flaxseed containing 52% ALA. A flaxseed variety containing 52% of the omega-3 fatty acid was used in the diet till the end of the trial (end of the 25th week). Appropriate percentage (8%) deductions in soyabean extract content of the control diet were done for the addition of crushed flaxseed.

3) Fish oil diet group were fed control diet +1% fish oil containing 7.5%EPA and 14.2% DHA. Sardine fish oil containing 7.5%EPA and 14.2% DHA from Blue line foods, Goa, India was used for fortification of control diet.

2.4. Nutritional and Elemental analysis

Analysis of mineral components of egg was conducted by an independent National Accreditation Board for Testing and Calibration Laboratories (NABL) laboratory, Department of Science & Technology, Government of India.

2.5. Fatty acid analysis in egg yolk

Fatty acid analyses of egg yolk was done by preparing methyl esters of the yolk fraction using the method of (Masood, Stark et al., 2005). The methylated yolk fatty acid samples were re-suspended in chloroform and quantified by gas chromatography (Arvindakshan, Sitasawad et al., 2003) performed on a Hewlett Packard gas chromatography, model 5890, series II using a capillary column on a fused silica gel capillary column 30 m x 0.32mm with a thickness of 0.25 (Supelco USA).

2.6. Cholesterol estimation in egg yolk

Estimation of cholesterol in egg yolk was carried out by atozyme cholesterol enzymatic kit. Briefly, cholesterol esters in the sample were first hydrolyzed by cholesterol esterase. Cholesterol was then oxidized by cholesterol oxidase to the corresponding ketone and hydrogen peroxide. 10-acetyl-3, 7-dihydroxyphenoxazine (ADHP) is utilized as a highly sensitive and stable probe for hydrogen peroxide. Horse radish peroxidase catalyzes the reaction of ADHP with hydrogen peroxide to yield the highly fluorescent product resorufin which is monitored using excitation wavelengths of 530-580 nm and emission wavelengths of 585-595 nm. (Kishi, Ochiai et al., 2002)

2.7. Estimation of vitamin E in egg yolk

Estimation of vitamin E was done by colorimetric method as described by Baker et al., 1968. Briefly, after the proteins in the yolk were precipitated using equal quantity of absolute ethanol, the entire mixture was extracted using an equal volume of n-heptane. The α, α -dipyridyl is then added to an aliquot of the upper layer to estimate the main interfering component, β -carotene at 460 nm. Tocopherols reduce ferric to ferrous ions and then forms a red colored complex with α, α' -dipyridyl which is read after 1.5 min in spectrophotometer at 520 nm.

2.8. Sensory analysis

Thirty seven volunteers aged 18-35 years (19 males and 18 females) were given were given six omega-3 enriched eggs per week to be consumed either as boiled eggs or fried eggs, and were given questionnaires to fill up. The eggs were to be taken either each once daily or two eggs thrice a week. The information for flavor, taste, mouth feel, yolk color, smell, texture, and

overall acceptability of the omega-3 enriched eggs was collected from each volunteer using a questionnaire (Ferrier et al., 1995).

2.9. Statistical analysis

Data were checked for normality and transformed to natural logarithms or ranks if needed. The statistical analyses were done by using SAS PROC MIXED version 9.2 (SAS Institute Inc, Cary, NC, USA). Student unpaired *t*-tests or least significant difference test were used to compare groups within an endpoint. A probability of $P < 0.05$ indicated a difference was significant, and a probability of $P > 0.05$ to $P < 0.1$ indicated that significance was approached. Data are presented as the mean \pm SEM.

3. Results

Fatty acid compositions of eggs of different commercial varieties from departmental stores in Jeddah are presented in Table 1. There was no significant difference among different varieties of eggs from the departmental stores with respect to the fatty acid composition. Table 2 shows the fatty acid compositions of eggs from hens fed flaxseed and fish oil fortified diets. The total saturated fatty acid content contributed by palmitic acid and stearic acid reduced significantly thereby reducing the PUFA: Saturated fatty acid ratio. The PUFA content of the two commercial egg varieties (13.71 ± 0.75 and 14.75 ± 0.41) was very less, though not significant, as compared to the omega-3 eggs (23.72 ± 1.51 and 21.37 ± 0.99) analyzed. The three omega-3 fatty acids ALA, EPA, & DHA were increased in all the omega-3 eggs studied. The omega-3 enriched eggs from the flaxseed source as well as fish oil source were quite comparable in terms of the omega-6: omega-3 ratio. The omega-3 enriched eggs exhibited a very low omega-6:omega3 ratio of 3.33 ± 0.43 and 2.75 ± 0.32 for the flaxseed and fish oil fed group respectively. Contrarily the commercial eggs analyzed from the two outlets showed a higher omega-6:omega3 ratio of 29.58 ± 1.45 and 32.17 ± 3.03 respectively. Sensory analysis to a group of volunteers showed that omega-3 eggs from the flaxseed source were more acceptable and palatable as compared to the ones produced using a fish oil source which exhibited a fishy after taste and odor.

Table 3 shows the elemental analysis of all the eggs studied. Potassium, vitamin D, E, B6, folate, and B12 levels showed a slight increase in the omega-3 eggs as compared to the commercially sold eggs.

4. Discussion

Egg being a nutrient dense, cheaply available, and commonly consumed food, needs to be assessed on its fatty acid composition, for improving its health components. Consumption of omega-3 fatty acids has been associated with improved health and fewer health related disorders. Omega-3 enriched eggs through their increased amounts of omega-3 fatty acids could confer benefits similar to that observed on consuming fish oil supplements. Satiety levels are increased on consumption of eggs (Vander Wal, Marth et al., 2005) thereby decreasing risk for metabolic disorders in overweight individuals according to a study by (Mutungi, Ratliff et al., 2008). Large population studies (Hu, Stampfer et al., 1999; Kritchevsky & Kritchevsky, 2000; Kritchevsky, 2004), show that consumption of one egg per day does no harm in increasing cholesterol levels in humans and poses no risk of CVD in non-diabetic subjects.

Also the omega-3 fatty acids from eggs are more bioavailable to humans as noted in earlier studies (Ferrier, Caston et al., 1995) and have the capacity to reduce heart disease risk (Oh, Ryue et al., 1991). Because of the benefits associated with omega-3 fatty acid, their levels in different types of eggs was evaluated. Evaluation of the levels of omega-3 fatty acids especially DHA in the commercial eggs sold in the Jeddah market, found them to be almost negligible. The commercial eggs also contained a high amount of saturated fat (45.28 ± 0.10 and 45.57 ± 0.14) as compared to all other omega-3 eggs analyzed which is around 39.19 ± 0.22 and 40.23 ± 0.52 for the flaxseed and fish oil fed groups respectively. Our preliminary trial of feeding different sources of omega-3 fatty acids from fish oil source and flaxseed source and depositing omega-3 fatty acids into egg yolks yielded good results. Minor differences were noticed in the omega-3 eggs produced from the flaxseed as well as fish oil source. It was found that omega-3 eggs could be produced from both ALA (flaxseed source) as well as DHA (fish oil source) which are quite comparable in terms of DHA, omega-6: omega-3 ratio, and MUFA/Saturated fatty acid levels. There was a slight non-significant increase in saturated fatty acid levels in the fish oil group as compared to the ALA (flaxseed source) group which may be due to the saturation in the fish oil. Major changes in diet were not possible as they affected the hen and egg parameters which have not been included in this study. As compared to omega-3 levels, the cholesterol levels in the commercial eggs studied did not vary considerably, (Milinsk, Murakami et al., 2003, Rowghani et al., 2007) though it was only slightly reduced in the omega-3 eggs.

In terms of fatty acid composition, a decrease in the saturated fatty acid levels and an increase in omega-3 fatty acid levels were noted. Thereby the omega-6: omega-3 ratios were considerably lower in omega-3 eggs than the commercial eggs studied. Our experiments show that omega-3 eggs have an edge over the commercial eggs in terms of cholesterol content, vitamin E content, potassium, vitamin D, E, B6, folate, and B12 as well as fatty acid analysis.

Mineral analysis showed an increase in the potassium and iron content of omega-3 eggs as compared to the commercial eggs showing a possible increase in absorption of these elements due to dietary changes. Omega-3 fatty acids may possibly enhance the utilization of these nutrients.

Eggs produced from fish oil source had a slight fishy unpleasant odor which would affect consumer compliance and palatability. This was in accordance to earlier results by Helenia et al., 2010. On the other hand the omega-3 PUFA enriched eggs produced using a flaxseed diet were found to be very similar to the regular country eggs in terms of odor, taste, and appearance, similar to findings of Marshall, Kubena et al., 1994.

Moreover 8% flaxseed (2.5 % ALA) can be bio –converted to almost the same amount of DHA (around 5%) as that of DHA fish oil feed of 1%. Therefore considering that both flaxseed and DHA feed can deposit almost the same amount of DHA into the egg, flaxseed seems a more economically viable proposition. Further studies on egg production and bird parameters with different feeds and different concentrations for a longer period of time are necessary to evaluate the economic feasibility of producing omega-3 eggs in Saudi Arabian conditions.

It has been shown that none of the commercially sold eggs in the Jeddah market contained significant amounts omega-3 fatty acids. Our study further showed that the healthy omega-3 fatty acids can be incorporated into the egg using both flaxseed as well as fish oil as a supplemental feed source and brought into the food chain. Therefore the intake of omega-3 eggs would contribute in achieving the recommended intake values of LC-PUFA's as given by the Nutrient Reference Values for Australia and New Zealand, 2006. Consumer awareness and preferences for better health benefits (Zhao, Chambers et al., 2007) would help in creating a healthier environment in Saudi Arabia.

5. Conclusion

Nutritionists all over now advise eating foods promoting health benefits, rather than the earlier avoidance therapy thereby adopting an overall holistic approach. Omega-3 enrichment in eggs and other nutritional products containing omega-3 fatty acids are universally accepted today for their protective health benefits. Due to the inadequacy of omega-3 fatty acids in the commercially available eggs in Jeddah, value addition of the existing commercial eggs is deemed necessary. Also as compared to the fish oil source, producing omega-3 eggs from flaxseed source could be a viable option to promote better health to the common man. Moreover as egg is consumed by people of all ages, this positive step towards omega-3 egg production would be quite instrumental in generating health awareness through a universally accepted product. A balanced diet comprises of all the three omega-3 as each one of them independently bears different properties and the conversion of ALA to EPA & DHA is variable according to age, gender and ailment. These omega-3 eggs from flaxseed fed group are unique in providing the parent ALA as well as the longer chained fatty acids EPA & DHA. Therefore the potential of omega-3 eggs appears bright as a marketing product in the near future.

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7. References

Ahmed.M.E and Abdelati .K.A. Effect of dietary graded levels of *Leucaena leucocephala* seeds on layers performance, egg quality and bird parameters. Int.J.Poult Sci. 2009; 8:475-479.

Al-Nozha, M.M., Al-Mazrou, Y.Y., Al-Maatouq, M.A., Arafah, M.R., Khalil, M.Z., Khan, N.B., Al-Marzouki, K., Abdullah, M.A., Al-Khadra, A.H., Al-Harthi, S.S., Al-Shahid, M.S., Al-Mobeireek, A. & Nouh, M.S. Obesity in Saudi Arabia. Saudi Med J.2005; 26(5), 824-829.

Al-Nozha, M.M., Arafah, M.R., Al-Mazrou, Y.Y., Al-Maatouq, M.A., Khan, N.B., Khalil, M.Z., Al-Khadra, A.H., Al-Marzouki, K., Abdullah, M.A., Al-Harthi, S.S., Al-Shahid, M.S., Nouh, M.S. & Al-Mobeireek, A. Coronary artery disease in Saudi Arabia. Saudi Med J.2004; 25(9), 1165-1171.

Alqurashi, K.A., Aljabri, K.S. & Bokhari, S.A. Prevalence of diabetes mellitus in a Saudi community. Ann Saudi Med.2011; 31(1), 19-23.

Amuna, P. & Zotor, F.B. Epidemiological and nutrition transition in developing countries: impact on human health and development. Proc Nutr Soc.2008; 67(1), 82-90.

Arvindakshan, M., Sitasawad, S., Debsikdar, V., Ghate, M., Evans, D., Horrobin, D.F., Bennett, C., Ranjekar, P.K. & Mahadik, S.P. Essential polyunsaturated fatty acid and lipid peroxide levels in never-medicated and medicated schizophrenia patients. Biol Psychiatry.2003; 53(1), 56-64.

Baba, N.H. Dietary intake and nutrition related disorders in Lebanon. *Nutr Health*.2000; 14(1), 33-40.

Baker, H., Frank, O; 1968. *Clinical vitaminology, methods and interpretation*. Interscience Publishers, John Wiley and sons Inc., New York, 172 .

Drewnowski, A. Concept of a nutritious food: toward a nutrient density score. *Am J Clin Nutr*.2005; 82(4), 721-732.

FAO-1994: website <ftp://ftp.fao.org/docrep/fao/005/ac911e/ac911e02.pdf>

Ferrier, L.K., Caston, L.J., Leeson, S., Squires, J., Weaver, B.J. & Holub, B.J. alpha-Linolenic acid- and docosahexaenoic acid-enriched eggs from hens fed flaxseed: influence on blood lipids and platelet phospholipid fatty acids in humans. *Am J Clin Nutr*.1995; 62(1), 81-86.

Gil, A., Ramirez, M. & Gil, M. Role of long-chain polyunsaturated fatty acids in infant nutrition. *Eur J Clin Nutr*.2003; 57 Suppl 1, S31-34.

Health Canada 1990. *Nutritional Recommendations*, Ottawa: Canadian Government Publishing Centre, 1990:24, 57.

Helenia D. Sedoski, Sarah K. Beamer, Jacek Jaczynski, Susan Partington, Kristen E. Matak. Sensory evaluation and quality indicators of nutritionally-enhanced egg product with w-3 rich oils. *LWT - Food Science and Technology*.2012; 47:459e464.

Herron, K.L. & Fernandez, M.L. Are the current dietary guidelines regarding egg consumption appropriate? *J Nutr*.2004; 134(1), 187-190.

Hoffman, D.R., Theuer, R.C., Castaneda, Y.S., Wheaton, D.H., Bosworth, R.G., O'Connor, A.R., Morale, S.E., Wiedemann, L.E. & Birch, E.E. Maturation of visual acuity is accelerated in breast-fed term infants fed baby food containing DHA-enriched egg yolk. *J Nutr*.2004; 134(9), 2307-2313.

Hu, F.B., Stampfer, M.J., Rimm, E.B., Manson, J.E., Ascherio, A., Colditz, G.A., Rosner, B.A., Spiegelman, D., Speizer, F.E., Sacks, F.M., Hennekens, C.H. & Willett, W.C. A prospective study of egg consumption and risk of cardiovascular disease in men and women. *JAMA*.1999; 281(15), 1387-1394.

Jiang, Z. & Sim, J.S. Consumption of n-3 polyunsaturated fatty acid-enriched eggs and changes in plasma lipids of human subjects. *Nutrition*.1993; 9(6), 513-518.

Khalid A Madani. Obesity in Saudi Arabia Bahrain Medical Bulletin.2000; 22(3)

Khan MA, Al-Kanhal MA. Dietary energy and protein requirements for Saudi Arabia: a methodological approach. EMHJ.1998; 4:68-75.

Kishi, K., Ochiai, K., Ohta, Y., Uemura, Y., Kanatani, K., Nakajima, K. & Nakamura, M. Highly sensitive cholesterol assay with enzymatic cycling applied to measurement of remnant lipoprotein-cholesterol in serum. Clin Chem.2002; 48(5), 737-741.

Kritchevsky, S.B. A review of scientific research and recommendations regarding eggs. J Am Coll Nutr.2004; 23(6 Suppl), 596S-600S.

Kritchevsky, S.B. & Kritchevsky, D.Egg consumption and coronary heart disease: an epidemiologic overview. J Am Coll Nutr.2000; 19(5 Suppl), 549S-555S.

Lewis, N.M., Seburg, S. & Flanagan, N.L. Enriched eggs as a source of N-3 polyunsaturated fatty acids for humans. Poult Sci.2000; 79(7), 971-974.

Marshall, A.C., Kubena, K.S., Hinton, K.R., Hargis, P.S. & Van Elswyk, M.E. n-3 fatty acid enriched table eggs: a survey of consumer acceptability. Poult Sci.1994; 73(8), 1334-1340.

Mary E, Van Elswyk. Nutritional and physiological effects of flax seeds in diets for laying fowl World's Poultry Science Journal.1997; 53: 253-264.

Massiera, F., Barbry, P., Guesnet, P., Joly, A., Luquet, S., Moreilhon-Brest, C., Mohsen-Kanson, T., Amri, E.Z. & Ailhaud, G. A Western-like fat diet is sufficient to induce a gradual enhancement in fat mass over generations. *J Lipid Res.*2010; 51(8), 2352-2361.

Masood, A., Stark, K.D. & Salem, N., Jr. A simplified and efficient method for the analysis of fatty acid methyl esters suitable for large clinical studies. *J Lipid Res.*2005; 46(10), 2299-2305.

Meluzzi, A., Sirri, F., Manfreda, G., Tallarico, N. & Franchini, A. Effects of dietary vitamin E on the quality of table eggs enriched with n-3 long-chain fatty acids. *Poult Sci.*2000; 79(4), 539-545.

Milinsk, M., Murakami, A., Gomes, S., Matsushita, M. & De Souza, N.)Fatty acid profile of egg yolk lipids from hens fed diets rich in n-3 fatty acids. *Food Chemistry.*2003; 83(2), 287-292.

Musa Freiji. The poultry industry in Arab world—Present and Future. *Lohmann Information.*2008; 43(1):44.

Musaiger, A.O. Diet and prevention of coronary heart disease in the Arab Middle East countries. *Med Princ Pract.* 2002; 11 Suppl 2, 9-16.

Musaiger AO, Musaiger AO. Nutritional status and dietary habits of adolescent girls in Oman. *Ecol Food Nutr.*1994; 31:227–237.

Mutungi, G., Ratliff, J., Puglisi, M., Torres-Gonzalez, M., Vaishnav, U., Leite, J.O., Quann, E., Oh, S.Y., Ryue, J., Hsieh, C.H. & Bell, D.E. Eggs enriched in omega-3 fatty acids and alterations in lipid concentrations in plasma and lipoproteins and in blood pressure. *Am J Clin Nutr.*1991; 54(4), 689-695.

Popkin, B.M. The nutrition transition and obesity in the developing world. *J Nutr.*2001; 131(3), 871S-873S.

Prentice, A.M. Nutrition and chronic disease: lessons from the developing and developed world. *Nestle Nutr Inst Workshop Ser.*2014; 78, 155-160.

Qureshi, A.I., Suri, F.K., Ahmed, S., Nasar, A., Divani, A.A. & Kirmani, J.F. Regular egg consumption does not increase the risk of stroke and cardiovascular diseases. *Med Sci Monit.*2007; 13(1), CR1-8.

Ramirez, M., Amate, L. & Gil, A. Absorption and distribution of dietary fatty acids from different sources. *Early Hum Dev*2001; 65 Suppl, S95-S101.

Rowghani, E., Arab, M., Nazifi, S., & Bakhtiari, Z. Effect of canola oil on cholesterol and fatty acid composition of egg-yolk of laying hens. *International Journal of Poultry Science.*2007; 6(2):111e114.

Ruxton, C. Recommendations for the use of eggs in the diet. Nurs Stand.2010; 24(37), 47-55; quiz 56.

Simopoulos, A.P. The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed Pharmacother.2002; 56(8), 365-379.

Singh, V.P. and N. Sachan. Designer eggs: A smart approach for health conscious persons. Poult. Planner.2010; 11: 21-23.

Sparks N. H. C. The hen's egg – is its role in human nutrition changing? World's poultry science Journal.2006; 62: 308-315.

Vander Wal, J.S., Marth, J.M., Khosla, P., Jen, K.L. & Dhurandhar, N.V. Short-term effect of eggs on satiety in overweight and obese subjects. J Am Coll Nutr.2005; 24(6), 510-515.

Yaffee, M, H. Schultz, J. Stone, S. Brokhari, and G. Zeidler. Consumer perception and utilization of eggs and egg products. Poultry Science.1991; 70: 188-192.

Yalcin, H. & Unal, M.K.The enrichment of hen eggs with omega-3 fatty acids. J Med Food.2010; 13(3), 610-614.

Zhao, X., Chambers, E.T., Matta, Z., Loughin, T.M. & Carey, E.E. Consumer sensory analysis of organically and conventionally grown vegetables. J Food Sci.2007; 72(2), S87-91.

Table1: Fatty acid analysis of commercial eggs from different outlets

Fatty acid	Outlet 1	Outlet 2
SFA-Myristate	00.07 \pm 0.04	00.11 \pm 0.01
SFA- Palmitate	32.50 \pm 0.06	32.40 \pm 0.25
SFA- Stearate	12.71 \pm 0.05	13.07 \pm 0.37
Oleate	40.87 \pm 0.86	39.50 \pm 0.55
Linoleic acid	11.37 \pm 0.59	12.33 \pm 0.39
Gammalinoleic acid	00.10 \pm 0.00	00.10 \pm 0.00
αAlpha Linolenic acid	00.23 \pm 0.03	00.23 \pm 0.03
Arachidonic acid	01.80 \pm 0.20	01.87 \pm 0.17
Eicosapentaenoic acid	00.00 \pm 0.00	00.00 \pm 0.00
Docosahexaenoic acid	00.22 \pm 0.02	00.22 \pm 0.02
Total Saturated fatty acid(SFA)	45.28 \pm 0.10	45.57 \pm 0.14
MUFA	40.86 \pm 0.86	39.50 \pm 0.55
n-6 PUFA	13.26 \pm 0.73	14.30 \pm 0.43
n-3 PUFA	00.45 \pm 0.03	00.45 \pm 0.03
Total PUFA	13.71 \pm 0.75	14.75 \pm 0.41
PUFA : Sat	00.30 \pm 0.02	00.32 \pm 0.01
MUFA : Sat	00.90 \pm 0.02	00.87 \pm 0.02
n6:n3	29.58 \pm 1.45	32.17 \pm 3.03

There was no difference in both groups in any of the individual fatty acids.

Table2. Fatty acid analysis of omega-3 eggs from different sources.

Fatty acid	Control	Flax seed source	Fish oil source	Probability
SFA-Myristate	00.07 ± 0.04	00.03 ± 0.03	00.03 ± 0.03	NS
SFA- Palmitate	32.57 ± 0.69	29.35 ± 1.35	31.17 ± 0.59	NS
SFA- Stearate	12.59 ± 0.12	10.47 ± 1.87	09.03 ± 0.42	NS
Oleate	39.40 ± 0.94 A	36.36 ± 0.84 B	38.19 ± 0.67 AB	P < 0.10
Linoleic acid	12.43 ± 0.18	15.15 ± 1.81	14.27 ± 1.11	NS
Gammalinoleic acid	00.10 ± 0.00	01.12 ± 1.04	00.08 ± 0.02	NS
AlphaLinolenic acid	00.13 ± 0.03 A	01.87 ± 0.51B	00.06 ± 0.04 A	P < 0.008
Arachidonic acid	01.83 ± 0.20	01.82 ± 0.10	01.35 ± 0.17	NS
Eicosapentaenoic acid	00.07 ± 0.03	00.19 ± 0.06	00.07 ± 0.04	NS
Docosahexaenoic acid	00.22 ± 0.02 A	03.57 ± 1.37 B	05.61 ± 0.28 B	P < 0.01
Total Saturated fatty acid(SFA)	45.22 ± 0.72 A	39.19 ± 0.22 B	40.23 ± 0.52 B	P < 0.0004
MUFA	39.40 ± 0.94	37.36 ± 1.83	38.19 ± 0.67	NS
n-6 PUFA	14.37 ± 0.14	25.16 ± 6.43	15.64 ± 1.21	NS
n-3 PUFA	00.42 ± 0.02 A	05.63 ± 0.82 B	05.73 ± 0.21 B	P < 0.0004
Total PUFA	14.78 ± 0.15 A	23.72 ± 1.50 B	21.37 ± 0.99 B	P < 0.002
PUFA : Sat	00.32 ± 0.01 A	00.59 ± 0.04 B	00.53 ± 0.03 B	P < 0.002
MUFA : Sat	00.87 ± 0.04 A	00.91 ± 0.01 AB	00.95 ± 0.01 B	P < 0.1
n6:n3	34.58 ± 1.34 A	03.33 ± 0.43 B	02.75 ± 0.32 B	P < 0.0001

NS= nonsignificant. AB= means with unlike superscripts are different (P < 0.05) by least significant difference test.

Test	units	Outlet 1	Outlet2	Control Diet	omega-3 eggs(from Flax source)	omega-3 eggs (from fish source)
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Table-3—Nutritional and Elemental analysis of the commercial egg, country egg and omega-3 enriched eggs from different sources

Nutritional analysis						
Weight	(g)	50.67	50.5	50.95	50.87	51.5
moisture	%	75.02	73.04	75.88	75.25	75.08
Fat	%	13.02	12.54	13.2	12.75	12.78
Cholesterol	(mg)	239.79	235.66	239.5	220.35	215.67
protein	%	12.12	12.22	11.8	12.1	12.2
energy value	Kcal	165.1	167.2	168	166.8	168
ash	%	1.01	1.21	1.25	1.18	1.01
Minerals and trace elements						
sodium	mg	124	121.6	125	120.8	122
potassium	mg	124.5	126	120	218	215
calcium	mg	50.2	50.18	48	50.28	50.54
phosphorus	mg	223.8	225	227	219	220
magnesium	mg	8.8	8.79	9.02	8.87	8.88
iron	mg	1.55	1.58	1.47	2.15	2.03
zinc	mg	1.00	1.015	1.1	1.09	1.13
copper	mg	0.014	0.013	0.009	0.011	0.014
iodine	mg	0.038	0.041	0.028	0.040	0.039
chlorine	mg	169.7	170.7	158	169.8	170.2
sulphur	mg	150.9	150.12	145	152.9	151.3
selenium	mg	ND	ND	ND	ND	ND
vitamins						
A	IU	628	635	620	642.8	652
D	IU	43.8	44.7	45.1	48.68	49.3
E	mg	0.98	1.2	1.1	1.79	1.82
Niacin	mg	0.061	0.065	0.05	0.062	0.07
B1	µg	0.05	0.051	0.038	0.051	0.046
B6	mg	0.128	0.132	0.133	0.138	0.139
Folate	µg	44.8	46.2	46.04	49.32	50.2
B12	µg	1.08	1.05	1.05	1.23	1.27
Biotin	µg	19.62	19.65	19.68	19.77	19.82
Pantothenic acid	mg	1.2	1.18	1.01	1.23	1.24