Manganese quantification in some Egyptian food items using inductively coupled plasma optical emission spectroscopy

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Abstract

The current study was conducted to measure the manganese content in nine different food groups. A cross-sectional study was designed; a total of 89 food items were randomly purchased from the main markets and hypermarkets in Alexandria Governorate, then digested by wet ashing procedure and finally analyzed using ICP-OES. The highest mean Mn value was obtained in the fat group (6.75 µg/g) compared to the other eight groups, followed by nuts (4.64 µg/g) and the protein-rich food group (4.52 µg/g), while meat and its products have the lowest mean of Mn (0.53 µg/g). Manganese content in food groups is strongly correlated with the food matrix, soil composition, and fortification process. Local butter, margarine, sunflower oil, corn oil, Scomberomorus commerson, poulti fish, pistachio, and walnuts had the highest content of manganese.

1. Introduction

Manganese is the twelfth most prevalent element in the Earth’s crust, and it may be found in soil, food, and water. This vital element occurs in many different oxidation states, the most common of which are Mn^{3+} and Mn^{2+} in mammalian tissues. Mn is participated in a variety of biochemical tasks, including carbohydrate, lipid, amino acid, and protein metabolism, immunological function and growth, regulation of cellular energy and blood glucose level, reproduction, and as a component in the detoxification of reactive oxygen species (ROS) (Anastacio et al., 2018; Aschner & Aschner, 2005; Erikson & Aschner, 2003). Manganese is distributed throughout body tissues such as: liver, thyroid, pituitary gland, pancreas, and kidneys, while bones have the highest amounts. A 70 kg man has a manganese level of approximately 12–20 mg. A manganese daily need has not been identified; nevertheless, a minimal consumption of 2.5 to 7 mg each day sufficient to meet human needs (Freeland-Graves et al., 2014).

Manganese is largely found in mitochondria, where it catalyzes various enzymes such as hydrolases, kinases, transporters, and dehydrogenase. Pyruvate carboxylase, which catalyses the conversion of pyruvate onto oxaloacetate, is one of the most well-known manganese-dependent enzymes (Freeland-Graves et al., 2014). Manganese activates enzymes responsible for protein synthesis and fatty acid metabolism, and is also involved in neuronal function (Freeland-Graves et al., 2014). Manganese content in foods can fluctuate because plant foods contain higher amounts than animal foods.

Manganese levels in nuts, rice, and grains are quite high. Furthermore, seafood, fruits, chocolate, seeds, spices, and leafy green vegetables are significant sources of Mn exposure via food (Aschner & Erikson, 2017). Mn can be present at lesser concentrations in beverages, including teas, water, and juices (Aschner & Erikson, 2017). Mn is absorbed in the gastrointestinal tract via active transport or passive diffusion after ingestion, and the metal absorbed may be integrated into metalloproteins such as glutamine synthetase, phosphoenolpyruvate dehydrogenase, arginase, manganese superoxide dismutase, and pyruvate carboxylase enzymes (Williams et al., 2012). In general, intestinal absorption accounts for less than 10% of consumed Mn, and homeostatic Mn balance is maintained through bile excretion and faecal excretion (Davis et al., 1993; Malecki et al., 1994).

Some aspects, such as iron storage level, dietary supplement...
consumption, and calcium or phosphorus intake, may alter Mn absorption and elimination (Greger et al., 1990; Institute of Medicine, 2001; Lutz et al., 1993; Meltzer et al. 2010). Manganese appears to be absorbed through the small intestine. Other elements, such as calcium, phosphorus, and soy protein, can interfere with its absorption (Watts, 1990). Although plant sources of manganese are plentiful, a vegetarian diet does not inevitably lead to increased manganese levels. This is because the high level of phytate inhibits the absorption of manganese. Human research has reported that those fed a high-protein diet have a more favorable manganese balance than those fed a low-protein diet (Aschner et al., 2005). The liver regulates manganese through bile secretion. However, if the hepatic excretory pathway is blocked or even overloaded, pancreatic secretion increases. The availability of manganese in the diet is clearly related to the manganese content in the tissues. Manganese is essential for proper thyroid function and is therefore important in the production of thyroid hormone (Soldin & Aschner, 2007). Tissue mineral analysis (TMA) investigations have shown that patients with hypothyroidism have low manganese levels because insulin, parathyroid hormone, and estrogen have antagonistic effects on thyroid function. Increased amounts of these hormones may affect the absorption or utilization of manganese (Watts, 1990). Manganese is important in the formation of cholesterol. Therefore, a deficiency of this precursor for regular hormone production could be associated with a manganese deficiency. Manganese and choline have a synergistic relationship (Watts, 1990). A lack of either or both of these nutrients may result in low mitochondrial and cell membrane function (Watts, 1990). Manganese deficiency has been reported in humans in cases where manganese was casually excluded from a pure diet. Symptoms include hypo-cholesterolemia, low triglycerides and phospholipids, weight loss, transient dermatitis, and intermittent nausea. Additionally, manganese deficiency can cause physiological problems, including poor growth, transient dermatitis, reduced fertility and birth defects, hypo-cholesterolemia, abnormal glucose tolerance, nausea, and vomiting (Burch et al., 1975; Friedman et al., 1987). Manganese deficiency may be associated with metabolic disorders like maple syrup illness and PKU (Hurry & Gibson, 1982). Manganese shortage is suspected in adults with Down syndrome who frequently experience secondary hip joint dislocations and epiphysitis of such femoral head (Watts, 1990).

Manganese deficiency might result in ammonium toxicity because manganese is necessary for the conversion process of ammonium ions into urea. Manganese toxicity from oral consumption is relatively uncommon. Manganese toxicity is generally induced by long-term exposure to manganese by workers in iron industries, manganese ore mining, welding, and chemical processing. Iron deficiency, alcoholism, chronic infections, and reduced excretion are all factors that can make you more susceptible to manganese toxicity (Watts, 1990). Mn can also accumulate in different parts of the brain, causing neurotoxicity by enhancing ROS production, inducing oxidative stress, mitochondrial malfunction, changes in neurotransmitters (dopaminergic and GABAergic), and cell death (HaMaI et al., 2001). Additionally, overexposure to Mn has been linked to neurological disorders, including Alzheimer’s disease, Parkinson’s disease, and amyotrophic lateral sclerosis in multiple investigations. Huntington’s disease models have been reported to have a selective absence of bioavailable brain Mn (Horning et al., 2013). Research on food composition was first carried out to identify and evaluate the chemical content of foods that have an impact on human health. Although manganese is an essential element in human biology, manganese concentration data is often missing from Egyptian food composition tables. The lack of data on its content in Egyptian foods may be a reasonable explanation because manganese is not included in Egyptian food ingredient tables. Therefore, the present study was conducted to determine the Mn content in different food groups using inductively coupled plasma optical emission spectrometry to facilitate formal decisions regarding dietary manganese intake among Egyptians.

2. Materials and methods

2.1. Chemicals

All standard solutions were purchased from Germany (Merk), including: Manganese standard solution, Nitric acid, Hydrochloric acid, and Hydrogen peroxide, while Deionized water was obtained from Petroleum Company with resistivity <18.6 Ohm

2.2. Data collection methods and tools

A cross-sectional study was conducted. Food items were classified into nine different food groups including; beverages, carbohydrate-rich food, milk, and its product, meat and its products, fruits and vegetables, protein-rich food, nuts, fats, and sweetened products. Nine to ten food items were collected from each food group giving a total of eighty-nine food items. A total of one kilogram or one liter of each food samples were purchased from different main hypermarket, fish market, or herbal market in Alexandria Governorate depending on the type of purchased food item. Each food item was purchased four times from four different markets in Alexandria governorate giving a total of 356 samples. Pooling was done for each food item (four replicates) by mixing them well together to obtain random and representative sample for each. Samples were purchased from January to April 2021.

2.2.1. Sample storage and preparation

Samples were collected and protected from manganese loss or contamination throughout the analysis. Meat, fish, and seafood were stored at −20°C till analysis. Yogurt, fruit, vegetables, and cheese were analyzed once purchased, while oil, nuts, and beverages were stored in opaque glass bottles at room temperature at 27°C until analysis. Dry solid samples were ground to give fine particles using a blender, while muscular samples such as meat and its products, and poultry were minced after discarding fats and connective tissue. On the other hand, only edible parts of seafood were analyzed; head, skin, viscera, scales, and tail were removed, vegetables and fruits were homogenized well in a porcelain mortar to obtain homogeneous samples. All prepared samples were kept in plastic pages till they were digested.
2.3. Sample digestion and quantification

Samples were digested according to the EPA method (Martin et al., 1994) using the ETHOS microwave digestion system. All samples were digested either by using HNO$_3$ (65%) or H$_2$O$_2$ (40%) and HCL according to the sample matrix. Samples were filtered through Whatman paper 0.4 then using syringe filter 0.2 µm pore. The obtained solution will make up to 50 ml. All the wet digested samples were ready for manganese quantification using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES).

2.4. Preparation of the standard curve for manganese

The standard curve was prepared from stock solution (1000 ppm) using deionized water. The following concentrations were prepared; 0.005, 0.05, 0.01, 0.5, 1.5, and 15 ppm.

2.5. ICP-OES conditions

2.5.1. Instrumentation

ICP-OES measurements were performed using ICP-Pro Series ICP-OES (Qtegra JSQS-2.11software) Dual-view, Qua Ex-Cell (Thermo Fisher Scientific, Germany).

2.5.2. Operating conditions of ICP-OES

| Power       | 1.2 KW |
|-------------|--------|
| Wavelength  | 257.610 nm |
| Plasma flow | 15 L/min |
| Aux. flow   | 1.5 L/min |
| Neb. flow   | 0.75 L/min |
| Replicate read time (S) | 10 Sec. |
| Sample uptake time | 30 Sec. |
| Rinse Time  | 10 S |
| Pump rate   | 15 rpm |
| Instrument stabilization delay | 15 S |

2.5.3. ICP – OES analysis

Manganese concentrations were calculated from the regression line ($R^2 = 0.999$) obtained using Mn standard solution (Merk) according to the EPA 200.7 method (Martin et al., 1994).

3. Statistical analysis of the data

The data was fed to the computer and analyzed using the IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp).

Qualitative data was described using numbers and percentages. The Kolmogorov-Smirnov test was used to verify the normality of the distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, and median. The significance of the obtained results was judged at the 5% level. The used tests were the Kruskal Wallis test; for abnormally distributed quantitative variables, to compare between more than two studied groups, and Post Hoc (Dunn’s multiple comparisons test) for pairwise comparisons.

4. Results and discussion

Data on manganese intake is very limited worldwide, but indicates that most people obtain adequate amounts of manganese in their diet. The National Health and Nutrition Examination Survey, which provides data on dietary intake for most nutrients, does not include data on manganese. Manganese deficiency is very rare in humans, and signs and symptoms of deficiency have not been consistently demonstrated. (Buchman, 2014; Nielsen, 2012) The federal government’s Dietary Guidelines 2020–2025 state that “Because foods provide a variety of nutrients and other ingredients that have health benefits, nutritional needs should be met primarily through food”. The dietary guidelines describe a pattern of healthy eating that includes a variety of vegetables, fruits, and the grains (at least half of whole grains) low-fat and non-fat milk, yogurt, cheese, and oils. Whole grains are rich sources of manganese. Some vegetables and fruits also contain manganese. Protein-containing foods like lean meats, poultry, eggs, and marine, beans, peas, and lentils have manganese. (Van Sant et al., 2022)

Mn content in Egyptian fenugreek was 2.3 µg/g as shown in Table 1. Mn concentration in Egyptian fenugreek is substantially higher than in Indian fenugreek (0.670 µg/g) (Kumaravel & Alagusundaram, 2014), but it is much lower than in Turkish fenugreek (8 µg/g) and Pakistani fenugreek (99.1 µg/g) (Naeem et al., 1995; Ozkutlu, 2008).

In terms of Mn content in nuts; pistachio seeds had the highest Mn value (11.6 µg/g). Furthermore, the value for walnuts in this study is higher than the value for Brazilian walnuts (Naeem et al., 1995). This could be linked to mineral enrichment of the Egyptian soil. Furthermore, regional and climatic variances may reflect the differences in Mn concentration in soil all over the world.

In terms of Mn content in sweetened items, black honey has the highest Mn value (7.8 µg/g), as indicated in Table 1. Interestingly, bee honey has a high Mn concentration (4.7 µg/g) (Tables 1 and 2). This value is higher than previously observed by Rashed and Soltan, who stated that the Mn content of Egyptian bee honey ranges from 0.50 to 1.70 µg/g (Rashed & Soltan, 2004). In comparison to earlier research, the Mn content in the present study is higher than that found in honey samples from Spain, Hungary, Brazil, Slovenia, and Croatia, which were 0.133–9.471, 0.026–4.23, 0.06–1.96, 0.3–2.3, and 0.18–3.77 µg/g, respectively (Bilandžić et al., 2017; Czipa et al., 2015; Fernández-Torres et al., 2005; Golob et al., 2005; Liberato et al., 2013). This variation could be attributed to the geographical and botanical origins of the honeys. The prevalence of various melliferous flowers and trees gathered by bees is related to soil composition, and but climatic factors and bee species differences.

In terms of Mn content in carbohydrate-rich foods, rice has the highest Mn value of 3.4 µg/g. This really is lower than the concentrations described by other studies from various nations (Adedire et al., 2015; Phuong et al., 1999; Wenlock et al., 1979). Mn content in fish varies greatly depending on the environment and season (Table 1) (Mosepele et al., 2009). According to the current study, Scomberomorus commerson and Tilapia fish have the greatest Mn concentration rather than other food items (14.6 and 11.2 µg/g, respectively). The Mn content of Mediterranean sea-fish in Alexandria is higher than that of fish from Lake Tanganyika in Burundi, which may be attributed to differences in marine habitats and seasons (Sindoigaya et al., 1994).

Mn contents in different fats clarified that Mn in local butter, local margarine, sunflower oil, and corn oil are 21.4,
### Table 1. Manganese content in different food items sold in Egyptian markets.

| Food group                   | Food items                                      | No. or replicates | Origin            | Concentration (µg/g ±SD) | Min-Max | 
|------------------------------|-------------------------------------------------|-------------------|-------------------|---------------------------|---------| 
| 1 Drinks and beverages      | Black tea (Camellia sinensis)                   | 4                 | Herbal market     | 0.3 ± 0.4                 | 0.20–2.30 | 
|                              | Instant coffee (coffee crystals, or coffee powder) | 4                 |                   | 0.9 ± 0.06                |         | 
|                              | Nescafe (brand of coffee either mixed with creamer or/and sugar) | 4                 |                   | 0.2 ± 0.08                |         | 
|                              | Mint (Mentha spicata)                           | 4                 |                   | 1.2 ± 0.15                |         | 
|                              | Ginger (Zingiber officinale)                    | 4                 |                   | 0.8 ± 0.5                 |         | 
|                              | Carob (Ceratonia Siliqua)                       | 4                 |                   | 0.5 ± 0.15                |         | 
|                              | Caraway (Carum carvi)                           | 4                 |                   | 1.2 ± 1.0                 |         | 
|                              | Roselle (Hibiscus sabdariffa)                   | 4                 |                   | 1.8 ± 0.5                 |         | 
|                              | Fenugreek (Trigonella Foenum-Graecum)           | 4                 |                   | 2.3 ± 0.7                 |         | 
|                              | Coca-cola (carbonated soft drink)               | 4                 |                   | 0.2 ± 0.07                |         | 
| 2 Nuts                       | Hazelnut (Corylus avellana)                     | 4                 |                   | 5.6 ± 3.88                | 0.50–11.60 | 
|                              | Almonds (P. amygdalus)                          | 4                 |                   | 4.5 ± 3.2                 |         | 
|                              | Pistachio (Pistacia vera)                       | 4                 |                   | 11.6 ± 1.8                |         | 
|                              | Sesame (Sesamum indicum)                        | 4                 |                   | 3.4 ± 1.8                 |         | 
|                              | Walnuts (Juglans)                               | 4                 |                   | 11.2 ± 1.0                |         | 
|                              | Peanuts (Arachis hypogaea)                      | 4                 |                   | 3.4 ± 2.12                |         | 
|                              | Sunflower seed (Helianthus annuus)              | 4                 |                   | 2.1 ± 0.09                |         | 
|                              | Watermelon seeds                               | 4                 |                   | 3.2 ± 0.5                 |         | 
|                              | Cashew (Anacardium occidentale)                 | 4                 |                   | 0.9 ± 0.8                 |         | 
| 3 Sweetened product         | Bee Honey (Floral Nectar)                       | 4                 |                   | 4.7 ± 2.63                | 0.20–7.80 | 
|                              | Black Honey                                    | 4                 |                   | 7.8 ± 2.0                 |         | 
|                              | Jam (whole fruit, pieces or crushed)            | 4                 |                   | 0.2 ± 0.06                |         | 
|                              | Sweet tahini (Middle Eastern condiment made from toasted ground hulled sesame and sugar) | 4 | | 4.6 ± 2.3 | | 
|                              | Chocolate biscuits (wafer biscuits)             | 4                 |                   | 3.2 ± 0.03                |         | 
|                              | Raw chocolate (Ground cacao seed kernels without added sugar) | 4 | | 0.8 ± 0.03 | | 
|                              | Dark chocolate Galaxy                          | 4                 |                   | 0.8 ± 0.05                |         | 
|                              | Diet biscuit (oats, and whole grain biscuits)   | 4                 |                   | 0.2 ± 0.06                |         | 
|                              | Gelatin (Gelatos)                              | 4                 |                   | 0.7 ± 0.3                 |         | 
|                              | Tea biscuits (plain)                            | 4                 |                   | 0.2 ± 0.09                |         | 
| 4 Carbohydrate rich food    | Rice (White, long-grain, regular, and unenriched) | 4 | | 3.4 ± 1.02 | 0.20–3.40 | 
|                              | Pasta (white pasta)                            | 4                 |                   | 2.2 ± 1.0                 |         | 
|                              | Corn (Zea mays)                                 | 4                 |                   | 1.2 ± 0.02                |         | 
|                              | Toast bread (Sliced white bread)                | 4                 | Bakery shop       | 0.2 ± 0.02                |         | 
|                              | Vino bread (White flour bread with cake improvers) | 4 | | 0.4 ± 0.02 | | 
|                              | Shami bread (White flour bread)                 | 4                 |                   | 0.6 ± 0.09                |         | 
|                              | Local bread (72% white flour)                   | 4                 |                   | 0.8 ± 0.02                |         | 
|                              | Potatoes (Solanum tuberosum)                    | 4                 |Hyper market       | 0.3 ± 0.05                |         | 
|                              | Sweet potato (Ipomoea batatas)                  | 4                 |                   | 0.3 ± 0.02                |         | 
|                              | Macaroni with whole grain (Brown pasta)         | 4                 |                   | 1.1 ± 0.6                 |         | 
| 5 Protein rich food         | Mullet fish (Flatehead grey mullet)             | 4                 | Fish market       | 1.3 ± 0.92                | 0.30–14.60 | 
|                              | Tilapia fish (Oreochromis niloticus)            | 4                 |                   | 11.2 ± 4.92               |         | 
|                              | Shrimps (Nantantia)                             | 4                 |                   | 4.5 ± 0.92                |         | 
|                              | Crabs (Liocarcinus verruca)                     | 4                 |                   | 6.8 ± 0.92                |         | 
|                              | Eggs (Chicken egg)                              | 4                 | Hyper market      | 0.8 ± 0.09                |         | 
|                              | Ducks (Muscovy duckling)                        | 4                 |                   | 3.4 ± 0.92                |         | 
|                              | Lentils (Lens culinaris)                        | 4                 |                   | 0.8 ± 0.2                 |         | 
|                              | Bean (P. vulgaris: Kidney Bean, Pinto Bean, Navy Bean) | 4 | | 0.3 ± 0.02 | | 
|                              | Chicken (Gallus domesticus)                     | 4                 |                   | 1.5 ± 0.05                |         | 
|                              | Scomoerbomorus commerson (Mackerel)             | 4                 |                   | 14.6 ± 0.2                |         | 
| 6 Fat group                 | Mora (Cooked butter with added salt)            | 4                 |                   | 0.3 ± 0.19                | 0.20–21.40 | 
|                              | Animal fat (Buffalo fat)                        | 4                 |                   | 0.4 ± 0.19                |         | 
|                              | Coconut Oil (Rich in saturated fatty acid)      | 4                 |                   | 2.1 ± 0.19                |         | 
|                              | Local margarine (Milk based product, natural source) | 4 | | 14.8 ± 8.19 | | 
|                              | Industrial butter (Made from vegetable oil)     | 4                 |                   | 0.2 ± 0.19                |         | 
|                              | Industrial margarine(Hyrogenated oil)           | 4                 |                   | 0.2 ± 0.1                |         | 
|                              | Local butter(Milk based product, natural source) | 4 | | 21.4 ± 2.4 | | 
|                              | Olive oil (Extra virgin oil)                    | 4                 |                   | 0.7 ± 8.19                |         | 
|                              | Corn oil (vegetable oil)                        | 4                 |                   | 12.8 ± 4.1                |         | 
| 7 Vegetables and fruits.     | Banana (Cavendish bananas)                     | 4                 | Grocery shop      | 0.3 ± 0.40                | 0.20–1.40 | 
|                              | Garlic (Allium sativum)                         | 4                 |                   | 0.4 ± 0.12                |         | 
|                              | Onions (Allium cepa)                            | 4                 |                   | 0.6 ± 0.01                |         | 
|                              | Tomatoes (Solanum lycopersicum)                 | 4                 |                   | 0.5 ± 0.008               |         | 
|                              | Orange (Sweet oranges)                          | 4                 |                   | 0.5 ± 0.02                |         | 
|                              | Apple (Malus domestica)                         | 4                 |                   | 0.4 ± 0.21                |         | 
|                              | Beet (Beta vulgaris)                            | 4                 |                   | 1.4 ± 0.07                |         | 
|                              | Lemon (Citrus limon)                            | 4                 |                   | 0.9 ± 0.30                |         | 
|                              | Carrots (Daucus carota subs. Sativus)           | 4                 |                   | 1.2 ± 0.02                |         | 
|                              | Cucumber (Cucumis sativus)                      | 4                 |                   | 0.2 ± 0.04                |         | 

(Continued)
Table 1. Comparison between the nine studied groups according to manganese content.

| Food group                  | Food items                                      | No. or replicates | Origin   | Concentration (μg/g ±S.D) | Min- Max. |
|-----------------------------|-------------------------------------------------|-------------------|----------|---------------------------|-----------|
| 8 Meat and its products     | Beef (Buffalo meat)                             | 4                 | Butcher shop | 0.7 ± 0.4 | 0.10–1.50 |
|                             | Kidneys (Buffalo origin)                        | 4                 |          | 0.8 ± 0.48               |           |
|                             | Liver (Buffalo origin)                          | 4                 |          | 1.1 ± 0.02               |           |
|                             | Kufta (Ground beef meat)                        | 4                 |          | 0.1 ± 0.05               |           |
|                             | Veal meat (Meat from calves, often dairy breeds)| 4                 |          | 0.4 ± 0.1                |           |
|                             | Sausage (Ground beef meat with spices)         | 4                 |          | 0.1 ± 0.00               |           |
|                             | Sheep meat (Ovis aries)                         | 4                 |          | 1.5 ± 0.32               |           |
|                             | Bastrama (Processed ground beef meat)           | 4                 | Grocery shop | 0.3 ± 0.02 |           |
|                             | Lancecon (Processed ground beef meat)           | 4                 |          | 0.1 ± 0.05               |           |
|                             | Susi(sausage)                                   | 4                 |          | 0.2 ± 0.01               |           |
| 9 Milk and dairy products   | Raw milk (Buffalo, and cow milk)                | 4                 |          | 0.5 ± 0.3                | 0.10–4.40 |
|                             | Full Cream Milk (Buffalo, and cow milk, different sold brands) | 4                 |          | 1.2 ± 1.0                |           |
|                             | Local yogurt (Lactobacillus fermented milk)     | 4                 |          | 0.3 ± 0.05               |           |
|                             | Full-fat yogurt (Available brands in markets)   | 4                 |          | 4.4 ± 0.007              |           |
|                             | Free-fat yogurt (Fat free available brands in markets) | 4                 |          | 2.8 ± 0.5                |           |
|                             | Rumi cheese (Aged saltiness hard cheese)        | 4                 |          | 0.2 ± 0.2                |           |
|                             | Soft cheese (Cottage, Creamy, Cord, and Farmer cheese) | 4                 |          | 0.4 ± 0.04               |           |
|                             | Semi-hard cheese (Cheddar, Gouda, and Edam cheese) | 4                 |          | 0.7 ± 0.05               |           |
|                             | Processed cheese (Mozzarella, Swiss, and sliced Cheddar cheese) | 4                 |          | 0.6 ± 0.05               |           |
|                             | Powdered milk (Dried milk)                      | 4                 |          | 0.1 ± 0.03               |           |

Table 2. Comparison between the nine studied groups according to manganese content.

| Groups                     | N   | Min. – Max. | Mean ± SD  | Median | H      | p       |
|----------------------------|-----|-------------|------------|--------|--------|---------|
| Drinks                     | 10  | 0.20–2.30   | 0.94 ± 0.70 | 0.85   | 22.149* | 0.005*  |
| Sweetened product          | 10  | 0.20–7.80   | 2.32 ± 2.63 | 0.80   |        |         |
| Carbohydrate rich food     | 10  | 0.20–3.40   | 1.05 ± 1.02 | 0.70   |        |         |
| Protein rich food          | 10  | 0.30–14.60  | 4.52 ± 4.92 | 2.45   |        |         |
| Fat                        | 10  | 0.20–21.40  | 6.75 ± 8.19 | 1.40   |        |         |
| Vegetables and fruits      | 10  | 0.20–1.40   | 0.64 ± 0.40 | 0.50   |        |         |
| Meat and its products      | 10  | 0.10–1.50   | 0.53 ± 0.48 | 0.35   |        |         |
| Milk and dairy products    | 10  | 0.10–4.40   | 1.12 ± 1.39 | 0.55   |        |         |

H: Kruskal Wallis test.
p: p value for comparing between the nine groups.
*: Statistically significant at p ≤ 0.05.
a: significant with drinks group.
b: significant with nuts group.
c: significant with sweetened group.
d: significant with carbohydrate group.
e: significant with protein rich food group.
f: significant with fat group.
g: significant with vegetables and fruits group.
h: significant with meat group.
H: Prueba de Kruskal Wallis.
p: valor p para comparar los nueve grupos.
*: Estadísticamente significativo a p ≤ 0.05.
a: significativo con el grupo de las bebidas.
b: significativo con el grupo de los frutos secos.
c: significativo con el grupo de los dulces.
d: significativo con el grupo de los carbohidratos.
e: significativo con el grupo de alimentos ricos en proteínas.
f: significativo con el grupo de las grasas.
g: significativo con el grupo de verduras y frutas.
h: significativo con el grupo de la carne.

14.8, 14.6, and 12.8 μg/g, respectively. These concentrations are significantly greater than that reported by Mac-Mahon for corresponding Turkish items (MacMahon, 2016). Despite the reality that vegetables and fruits contain low amounts of Mn due to their high water and low protein content, the current study found that the Mn values in beet, carrots, and lemon are 1.4, 1.2, and 0.9 μg/g, respectively, as shown in Table 1. This could be related to agricultural operations that influence Mn levels in foodstuffs, as Mn is being added to fertilizer to boost Mn levels in cultivated plants and, indirectly, improve Mn status in humans (Skupien & Oszmianski, 2007).

The highest amount of Mn was identified in sheep meat (1.5 μg/g) (Tables 1 and 2), which is lower than the values
(2.89–32.67 µg/g) reported by earlier studies from different countries (Alturqi & Albedair, 2012; Badis et al., 2014; Caggiano et al., 2005; Mendil & Tuzen, 2011). These variations could be attributed to variances in animal feeding techniques in Egypt versus other countries. The highest levels of Mn were found in full-fat yogurt, free fat yogurt, and full cream milk, with measurements of 4.4, 2.8, and 1.2 µg/g, respectively, as indicated in Tables 1 and 2. On comparing the significance between the nine studied food groups shown in Table 3, we found that there is a significant difference between many groups (p < .05), while there was a strong significant difference between nuts versus meat and its products as p < .001.

5. Conclusions and recommendations
The richest sources of Mn in Egyptian items are the fat group, followed by nuts. However, the meat group and vegetables and fruits are the lowest sources of Mn. Local butter, local margarine, sunflower oil, corn oil, Scomberomorus commerson, mullet fish, pistachio, and walnuts are the richest sources of Mn in the Egyptian diet. Even though nuts have a high content of Mn, it does not mean that they are important sources of manganese in the diet as they are not consumed in a significant amount. Meanwhile, some items, such as vegetables, carbs, fruits, and milk products, have a lower proportion of Mn but they are taken in considerable quantities. There are no concerns about the expectation of Mn deficiency among Egyptians since no estimation of dietary reference intake was performed. The researchers advise that more research should be done on the remaining unsearched Egyptian foods to help calculate Mn intake among Egyptians to get an accurate data of their condition.

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