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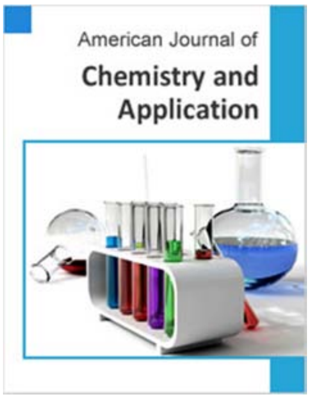

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Levels of Major and Minor Elements in Some Commercial Baby Foods Available in Libya

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Abstract
Nine (9) selected Infant formula from the Libyan market were analyzed by Atomic Emission Spectrophotometry (MP-AES) to assess the level of some heavy metals (Na, K, Ca, Fe, Cu, Mg, Cr, Cd, Pb, Ni and As) in them. The concentrations of heavy metals in the samples ranged from 150.98 to 670.91 $\mu g.g^{-1}$, 90.41 to 360.85 $\mu g.\ g^{-1}$, 150.98 to 420.08 $\mu g.\ g^{-1}$, 1.47-4.67$\mu g.g^{-1}$, 1.5–2.5 $\mu g.g^{-1}$, 10.34 to 20.14 $\mu g.\ g^{-1}$, 0.01-0.08 $\mu g.g^{-1}$, 0.013 to 0.032 $\mu g.g^{-1}$, 0.013 to 0.022 $\mu g.g^{-1}$, 0. 25 to 0.73 $\mu g.g^{-1}$, 0.012 -0.025 $\mu g.g^{-1}$, for Na, K, Ca, Fe, Cu, Mg, Cr, Cd, Pb, Ni and As respectively. The result of elemental analysis indicates that the order of abundance of metals in the infant food as follow Na > Ca>K>Mg>Fe>Cu>Ni>Cr>Cd>As>Pb. levels of the metals in the samples were less than acceptable limits in foods as specified in international guidelines.

1. Introduction

Approximately 30 elements are recognized to be essential for life. Whereas some of them such as Ca, K, Mg and Na are required in macronutrient amounts, others occur in trace or ultra trace quantities. Cu, Fe, Ni, Zn, and Mn are at the top end of this trace scale and play an important role in biological systems. On the other hand, some elements (e.g., Pb and Cd) are non-essential elements and toxic even in trace amounts [1]. There is much evidence that the quality and composition of commercial fruit baby food may contribute to present and future health benefits of young children. Since infants between 6 month and 3 years of age are rather limited in their food choices, the commercial fruit baby foods serve as the important source of energy, basic nutrients, fiber, vitamins and minerals and establish their taste and eating patterns. Whereas food safety of baby food from the view of chemical pollution and microbiological contamination is a priority for both producers and state authorities, the composition and nutritive quality of products are often underestimated [2].

Trace elements can be divided from a dietary point of view into three groups; the essential trace elements (micronutrients) which are constituents of hormones, vitamins and catalysts for the enzyme systems for the metabolic processes in the cells and they function at low concentrations in living tissues; the possibly essential trace elements; and the non-essential trace elements; which are made up of the toxic and non-toxic elements which have no metabolic functions in the living organism [3]. The roles of the essential trace elements in human health and disease have been documented in the literatures [4-6] and of particular interest is the role these trace elements play in human nutrition and infant nutrition [7-8]. Report of a working party of the panel on Child Nutrition has indicated the presence of these trace elements in human milk which are essential for infants [10].

Babies and small children are an especially sensitive population to exposure to environmental contaminants. Their small mass and developing systems, including brain development may show adverse health effects from even low levels of contamination on a chronic or single dose case. Foods, infant formula, milk, and water provide significant exposure routes for metal contaminants.

Although baby food and juice may contain metals from fruit grown in contaminated soil or introduced during the manufacturing process [11]. Europe has examined the problem more carefully and several elements are regulated in a variety of foodstuffs through Commission Regulation (EC) No 1881/2006 [12].

World Health Organization report recommends exclusive breastfeeding for the first 6 months of life [13], however, sometimes breast feeding is not sufficient [14] or if the mother is taking a particular drug that could harm the baby [15] or after six (6) months feed, then complementary feeding becomes necessary [14]. It obvious that infant baby food products produced in Libya have not been fully and comprehensively investigated to determine its trace and minor elemental content, especially in commercial infant cereal formula. For that, the need for the routine monitoring of these infant food products cannot be overemphasized. We have therefore carried out this work in order to have an up to date knowledge on the infant baby food in Libya.

2. Material and Methods

2.1. Sampling

Different branded baby foods from different area of Misurata region and pharmacies were purchased in 2013 in Misurata, Libya. A pool of samples was prepared by combining portion of each brand. An aliquot of this pooled sample was divided in to three portions and each was analyzed separately.

2.2. Sample Digestion and MP-AES Analysis of Samples

The cleaning procedures for the sample containers, microwave vessel, glassware for standard and MP-AES sample for metal determination was performed as per the procedure recommended by American Public Health Association [13] with slight modifications. In brief, all the containers were washed with metal free non-ionic detergent solution, rinsed with several times with any element free double distilled demonized water prior to use. Between 0.3 - 0.5 g sample of baby food was placed into Teflon bomb and digested with 7 mL Nitric acid on the microwave work station. The condition of microwave was set as temperature 25 - 170°C for 10 min and 170°C for another 10 min at 1000 W, followed by immediate ventilation at room temperature for 20 min. The acid digested samples were diluted with 50 mL ultra pure water in 50 mL volumetric flask. All samples were analyzed in triplicates by MP-AES (Agelent; USA).

2.3. Method Validation

For the precision and accuracy of the method, standard whole powdered milk purchased from National Institute of Standard and Technology (NIST) Gaithersburg, MD, USA. The milk standard, mixed reagent and individual elements' standard 100 mg/mL were procured from Sigma, Co. (USA) and were analyzed routinely for the purpose of accuracy. Recovery assays were satisfactory, ranging from 98 to 101%. Limit of detection and precision of all elements were calculated. Ultra pure water of noted resistance was used in all the process. Nitric acid and HCL were of spectroscopic grade (Merck Germany), Standard Solution of Na, K, Ca, Fe, Cu, Mg, Cr, Cd, Pb, Ni and As were prepared by dilution of 1 mg/ mL. Fluka (Kamica, Switzerland) of each metal.

Table 1. *Baby food packaging and their characteristics.*

No sample	Sample characteristics	Package type
1	Pulp of fruits and vegetables mixed	Glass bottle
2	Fruit paste of carrot, apple and guava	Glass bottle
3	Pulp carrot and apple	Glass bottle
4	Pulp banana and apple	Glass bottle
5	Pulp Mixed fruit	Glass bottle
6	Rice based with vegetables	Paper box
7	Rice based with apple	Paper box
8	Cereal with milk based, wheat, honey and Rice	Paper box
9	Cereal with Rice and honey	Paper box
10	Rice based with Fruits	Paper box

2.4. Data Analysis

All measurements were carried out in triplicate, and presented as mean ± standard deviation (SD). Significant differences among mean values, where applicable, were determined by one-way analysis of variance (ANOVA). A p value <0.05 was considered statistically significant. For all statistical calculations statistical package of software SPSS 20 was used [14].

3. Results and Discussion

For the purpose of validation of the method, the limit of detection (LOD = 3xSD/m), the limit of quantification (LOQ = 10xSD/m) for each metal were computed, where SD is the standard deviation of reagent blank and m is the slope of the calibration graph; correlation coefficient of the calibration curve for each metal were also determined and are shown in Table 2.

***Table 2.** Limit of detection (LOD), limit of quantification (LOQ) and correlation coefficient of the calibration for each mineral determination.*

Element	Correlation Coefficient	LOD (µg.ml^{-1})	LOQ (µgmL^{-1})
Na	0.999965	0.056773	0.189244
K	0.999887	0.275326	0.917754
Ca	0.999746	0.873115	2.910384
Fe	0.996837	0.659748	2.199165
Cu	0.999973	0.136850	0.456178
Mg	0.999765	0.658875	2.196254
Cr	0.998578	0.246542	0.821807
Pb	0.998784	0.095661	0.318874
Cd	0.989189	0.335895	1.119659
Ni	0.999986	0.079955	0.266517
As	0.997973	0.107418	0.358068

The mean and range results of heavy metal concentration in the baby food are presented in Table 3. All the Baby food samples analyzed were found to contain lead, nickel, copper, zinc, cobalt, cadmium, chromium and manganese in varying concentrations. The content of Na reached 382µg. g^{-1}, followed by Ca, K, Mg and Fe. The contamination of the baby food tested has an impact on the health of the society in general. It has an implication on the manufacturers, the distributors, the consumers and all parties involved in the cycle of handling the product.

***Table 3.** The Determined Values of the Elements Contents (µg/g) in Different Kind of Baby foods (Mean ± S.D., N=15 in triplication for each sample).*

As	Cu	Ni	Cd	Pb	Cr	Mg	Fe	Ca	K	Na	Sample NO.
0.021± 0.02	0.48± 0.05	0.25± 0.09	0.092± 0.01	0.022± 0.02	0.03± 0.008	13.09± 0.03	2.54± 0. 04	220.87± 0.02	120.94± 0.79	220.98± 0.22	1
0.012± 0.01	0.54± 0. 03	0.37± 0. 05	0.024± 0.01	0.015± 0.008	0.05± 0.009	10.45± 0.023	3.32± 0.01	360.87± 0.08	90.41± 0.74	310.97± 0.31	2
0.025± 0.03	0.93± 0.06	0.28± 0.07	0.015± 0.02	0.018± 0.07	0.01± 0.003	15.14± 0.04	4.33± 0.07	250.91± 0.08	160.22± 0.78	200.45± 0.89	3
0.019± 0.04	0.58± 0.06	0.32± 0.04	0.019± 0.04	0.013± 0.005	0.06± 0.001	18.23± 0.09	3.40± 0.01	150.98± 0.01	160.00± 0.33	380.62± 0.27	4
0.015± 0.01	1.63± 0.007	0.33± 0.08	0.013± 0.02	0.016± 0.09	0.02± 0.009	10.34± 0.05	2.52± 0.08	260.59± 0.01	190.12± 0.26	150.98± 0.96	5
0.020± 0.09	1.58± 0.08	0.54± 0.09	0.026± 0.02	0.019± 0.08	0.04± 0.007	12.75± 0.07	1.47± 0.02	320.96± 0.09	270.12± 0.35	670.91± 0.17	6
0.018± 0.08	1.34± 0.03	0.73± 0.14	0.044± 0.05	0.014± 0.01	0.05± 0.003	20.14± 0.09	3.44± 0.06	260.91± 0.08	260.50± 0.19	420.86± 0.12	7
0.017± 0.03	1.78± 0. 04	0.48± 0.07	0.018± 0.03	0.015± 0.03	0.06± 0.002	15.98± 0.01	4.67± 0.08	280.41± 0.05	500.78± 0.28	500.87± 0.19	8
0.018± 0.02	1.82± 0.05	0.63± 0.09	0.023± 0.01	0.017± 0.09	0.08± 0.008	17.82± 0.07	2.39± 0.01	420.08± 0.01	500.85± 0.18	580.92± 0.23	9

Magnesium assists calcium to help transmit nerve impulses in the brain. Both elements give relief to patients having depression. [18] Figure 1 shows the distribution pattern for Mg in the baby food samples with a mean of 14.882 µg. g^{-1}, over the range of 10.34 to 20.14 µg. g^{-1}. The obtained results lied below the permissible limit (628.7±0,23.847ppm) obtained by Al-Khalifa *et al.*[19]

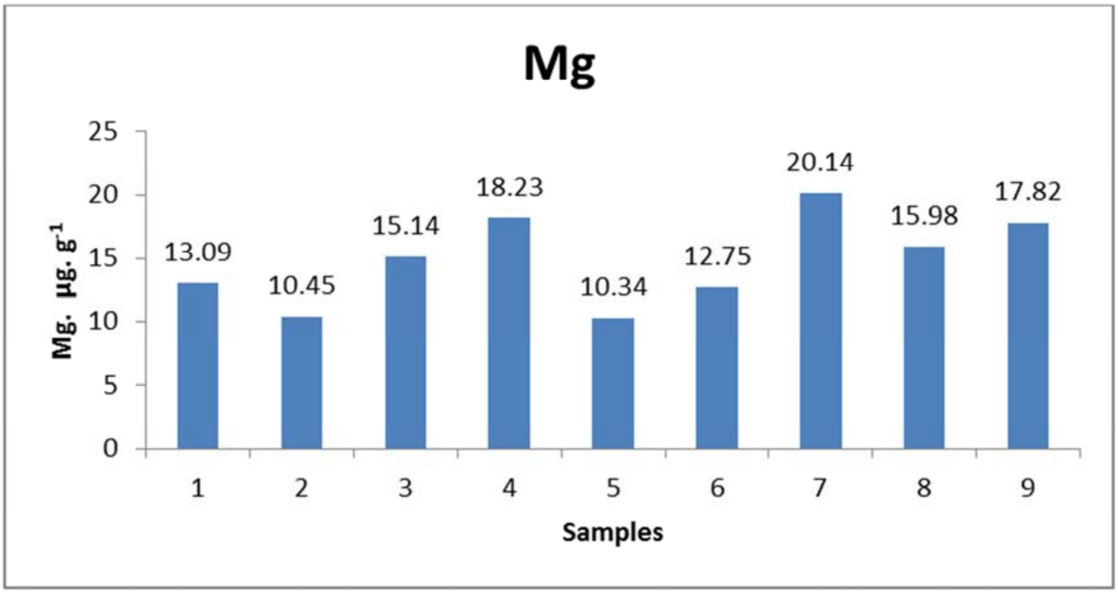

***Figure 1.** Distribution of Magnesium in baby food Samples.*

Chromium, Cr concentration range from 0.01-0.08 $\mu g.g^{-1}$. The major factors governing the toxicity of chromium compounds are oxidation state and solubility. Dermal exposure to chromium has been demonstrated to produce irritant and allergic contact dermatitis [20]. Chromium level detected in all the samples observed in the present study, which is an indication of manufactures' special designed in baby foods to complete the requirements. The balance amount of essential elements plays an important role in the metabolism of lipid, carbohydrate, protein and insulin [21]. Proper complimentary feeding of infants is crucial for their proper development, low level of essential elements has adverse effects and decrease immunity.

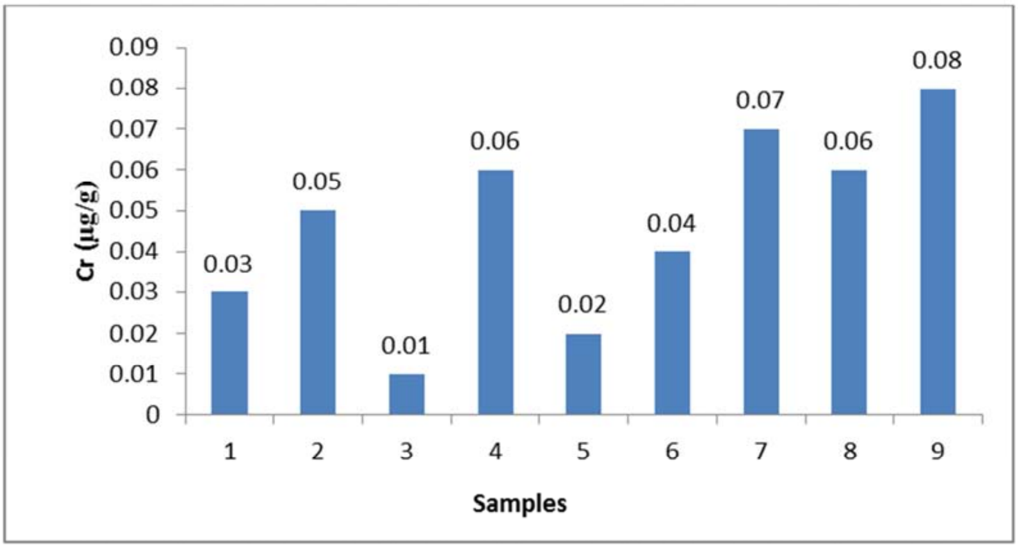

Figure 2. *Distribution of Chromium in baby food Samples.*

The concentrations of Lead range from 0.013 to 0.022 $\mu g.g^{-1}$. These shows that the level of lead in the samples are within the permissible limits, Hence, none of the baby food exceeded the limit of lead in this study. However, the presence of lead in infant food is of great concern since infants are very sensitive to its toxic effects. Childhood exposure to lead may induce suppression of mental capacity or retardation the set limits of international pediatric guidelines for baby which causes a high negative association between lead exposure and children's intelligence quotient. The presence of Lead in food may possibly be due to contamination during industrial food production, food handling or leakage of metals from packing materials. A number of factors can modify the impact of lead exposures. For example, water with a lower pH (such as drinking water stemming from the collection of untreated "acid rain") will leach more lead out of plumbing connected by lead solder than more alkaline water [22].

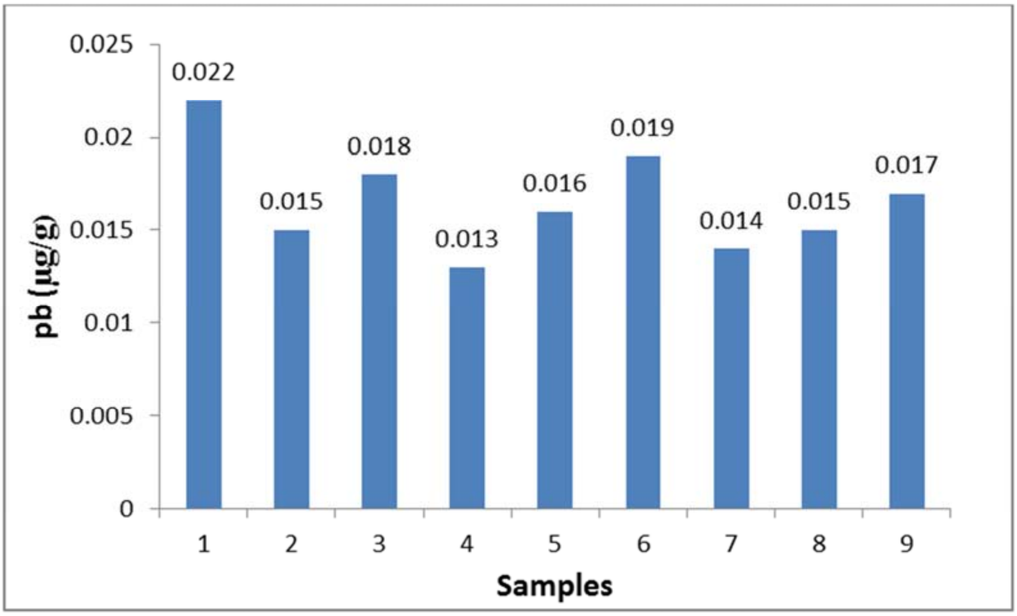

Figure 3. *Distribution of Lead in baby food Samples.*

The concentration of Cadmium ranged from 0.013 to 0.032 $\mu g.g^{-1}$. Implications of cadmium exposure are exacerbated by the relative inability of human beings to excrete cadmium. (It is excreted but then re-absorbed by the kidney.) Acute high-dose exposures can cause severe respiratory irritation. [23]. Cadmium was analyzed in all the samples but none of the sample exceeded the 5 µg /l as set limit according to EC Regulation by American public Health Association [24] and Kiely [25]. However, cadmium was more observed in cereals based samples as compared to other baby foods. Cadmium is also a matter of concern due to its carcinogenic effect and can lead to kidney dysfunction [26]. It is very clear entrance of lead and cadmium in cereal based food may lead through water or ingredients were used in preparation during processing. The levels of lead and cadmium in all analysed baby food samples were found to be higher values than those values reported by Bona [27].

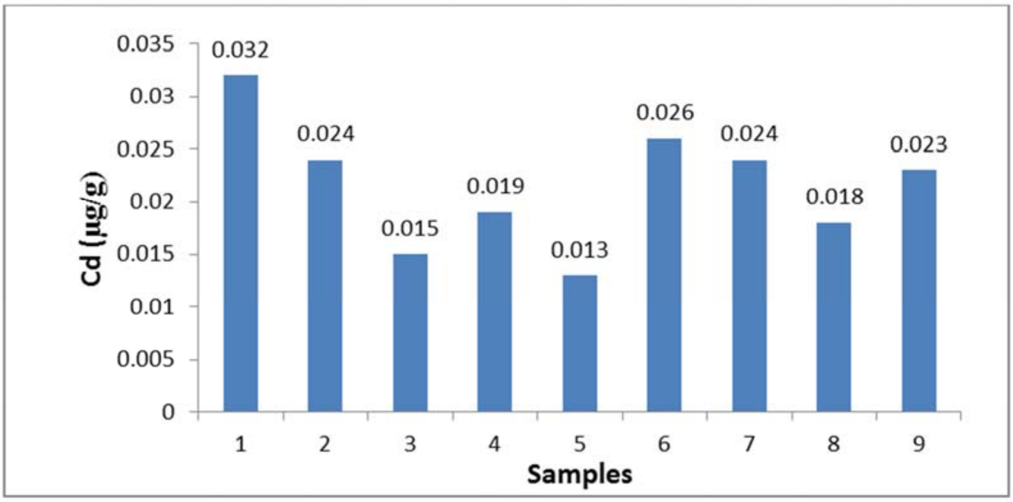

Figure 4. *Distribution of Cadmium in baby food Samples.*

The mean levels of nickel in the different brands spanned from 0. 25 to 0.73 $\mu g.g^{-1}$. The highest concentration of nickel was observed in sample '7'. The concentrations of nickel reported in the present study were higher than that levels reported in the literature. [28-30]

The main source of nickel in infant foods may possibly be due to cocoa additive which is known to contain elevated concentrations of nickel [31]. In addition, the contamination of raw materials and leaching of a nickel-chromium plated container during processing could be a source.

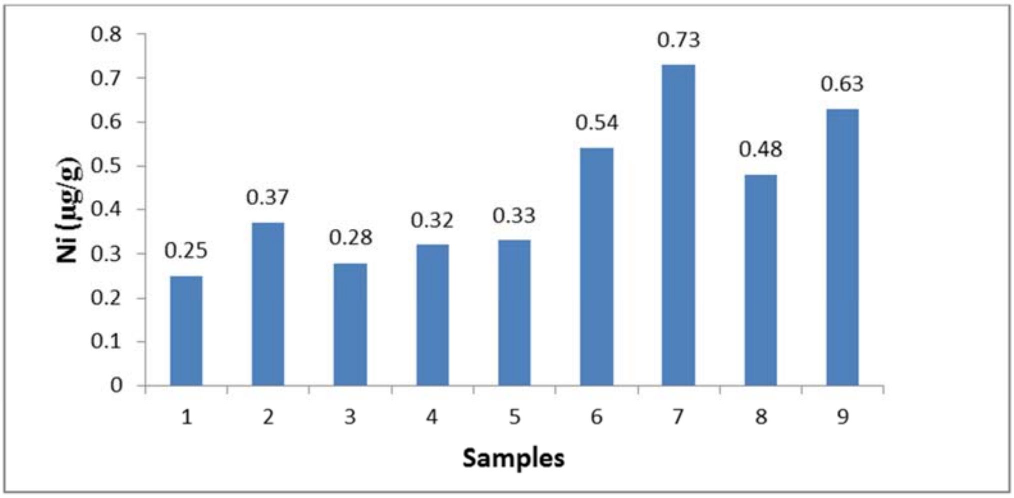

Figure 5. *Distribution of Nickel in baby food Samples.*

The mean concentrations of copper in these baby food ranged from 0.48 -1.82 $\mu g.g^{-1}$. The MAL of copper in infant food is 1.5–2.5 $\mu g.g^{-1}$. [32] The concentrations of copper found in this study were below the maximum allowed limits and no health hazard is expected from copper in the consumption of these brands of infant foods. Tripathi et al.[33] reported concentrations of copper in infant foods in India of 1.106.–3.157 $\mu g.g^{-1}$. The concentrations of copper recorded in this study are lower than values reported by these researchers.

Copper is an essential element for human and adverse health effects are related to deficiency as well as excess. Copper deficiency is associated with anaemia, neutropenia (decreased number of neutrophilic lymphocytes in the blood) and bone abnormalities [34].

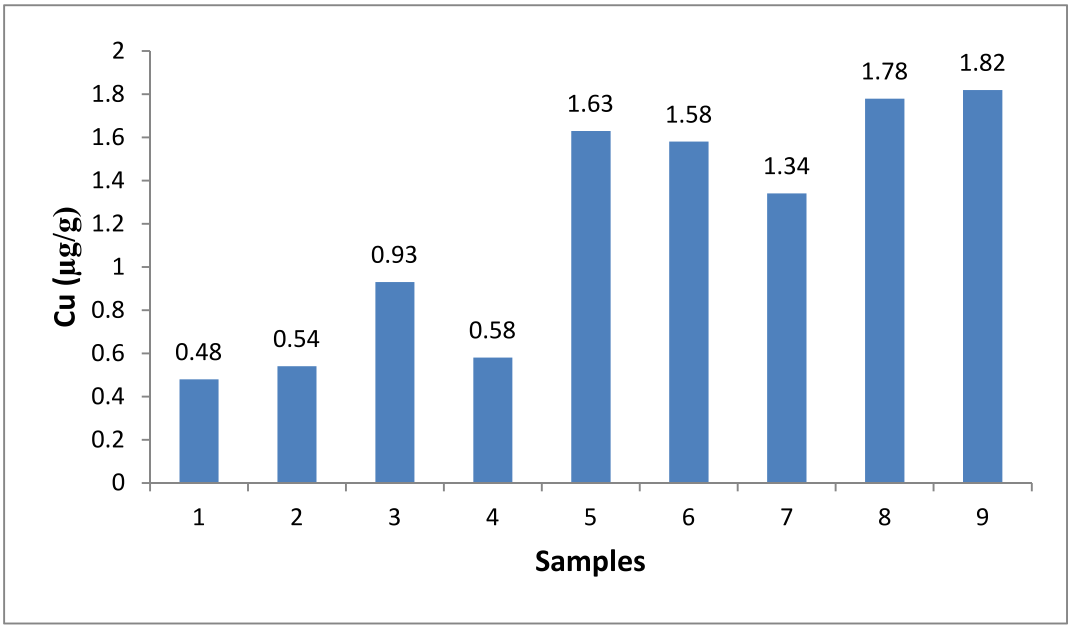

Figure 6. *Distribution of Copper in baby food Samples.*

The results show very low levels of arsenic measured in the baby food ranged from 0.012 -0.025 µg.g^{-1}. The standard deviations are very low showing good agreement between the three replicates measured on each sample.

Arsenic is ranked as one of the top three most hazardous substances in the priority list of toxic metals compiled by Environmental Protection Agency, the Agency for Toxic Substances and Disease Registry (ATSDR) in 2001 [35].

These quantities are lower than the values obtained by Al Khalifa and Ahmad. [36] Continuous exposure to lower levels of exposure to arsenic may cause nausea, vomiting, diarrhea, decreased production of red and white blood cells, abnormal heart rhythm, blood vessel damage, a "pins and needles" sensation in hands and feet, shock, coma, convulsions, irritation, inflammation, ulceration of mucous membranes and skin. [37]

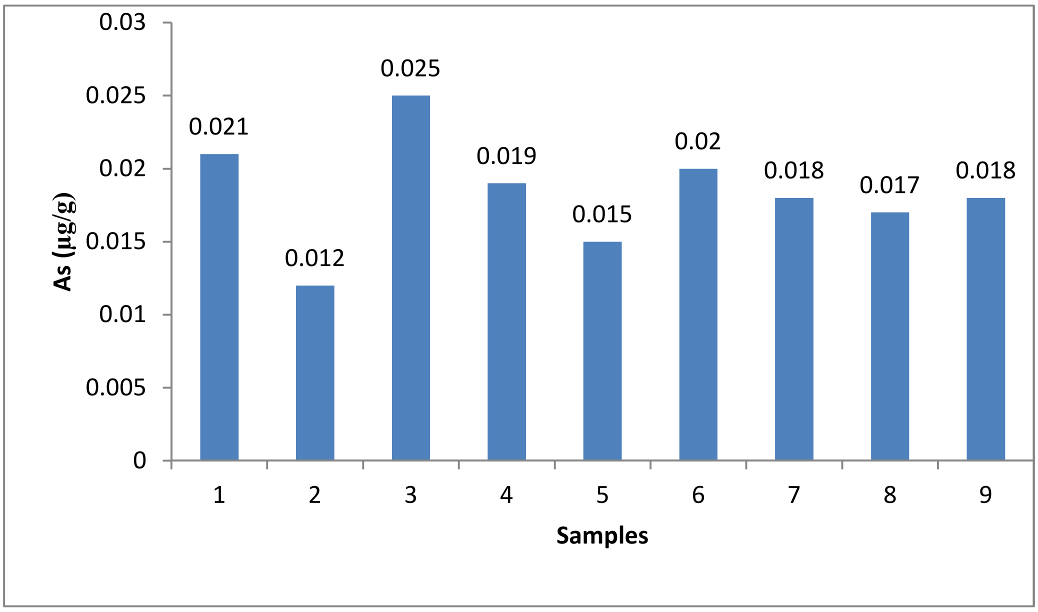

Figure 7. *Distribution of Arsenic in baby food Samples.*

Figure 8 shows the distribution pattern of iron, with a range of 1.47-4.67µg.g^{-1}, and a mean value of 3.12 µg. g^{-1}. Iron is deliberately added into the infant formula in order to meet the dietary requirement for iron. The concentrations of iron observed in this study were below the permissible levels. In Turkey, the concentrations of iron in infant foods were in the range 1.02–67.5 µg.g^{-1} [29]. An essential nutrient, especially for growing children, iron levels were examined as a means of studying the effects of farming techniques on the levels of metal ions that should be present in food. One of the claims made in terms of organically grown vegetables over those grown using conventional farming methods is the prevention of nutrient loss.

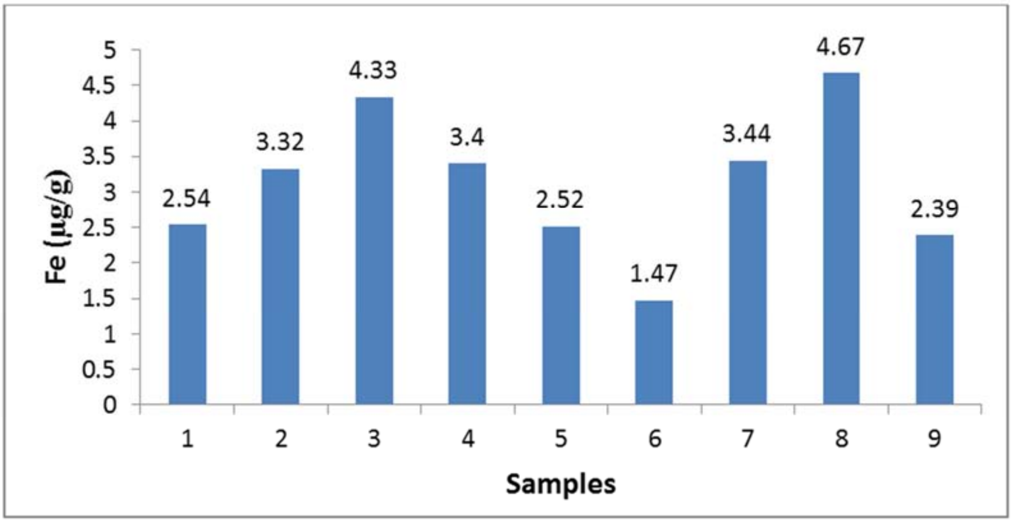

Figure 8. *Distribution of Iron in baby food Samples.*

The level of calcium in baby food ranged from 150.98 to 420.08 µg. g^{-1}, with a mean of 280.7 µg. g^{-1}; the highest content of calcium was in sample (9) and the lowest content was in the sample (4).

Calcium, Ca which about 99% is found in the skeleton and other parts such as the plasma, extravascular fluid, amongst other parts [38] is measured in all the samples, and this explains the importance of Ca intake to the human life. Ca requirements are affected substantially by genetic variability and other dietary constituents, and the interactions of these factors make identification of a single unique number for calcium 'requirement' for all children impossible [39, 40]. It is recognized that a very low calcium intake can contribute to the development of rickets in infants and children, especially those consuming very restrictive diets such as macrobiotic diets [41, 42]; even though there are no reliable data on the lowest calcium intake needed to prevent rickets or on the relationship among ethnicity, Vitamin D status, physical activity, and diet in the causation of rickets in children fed with low-calcium diets. [43].

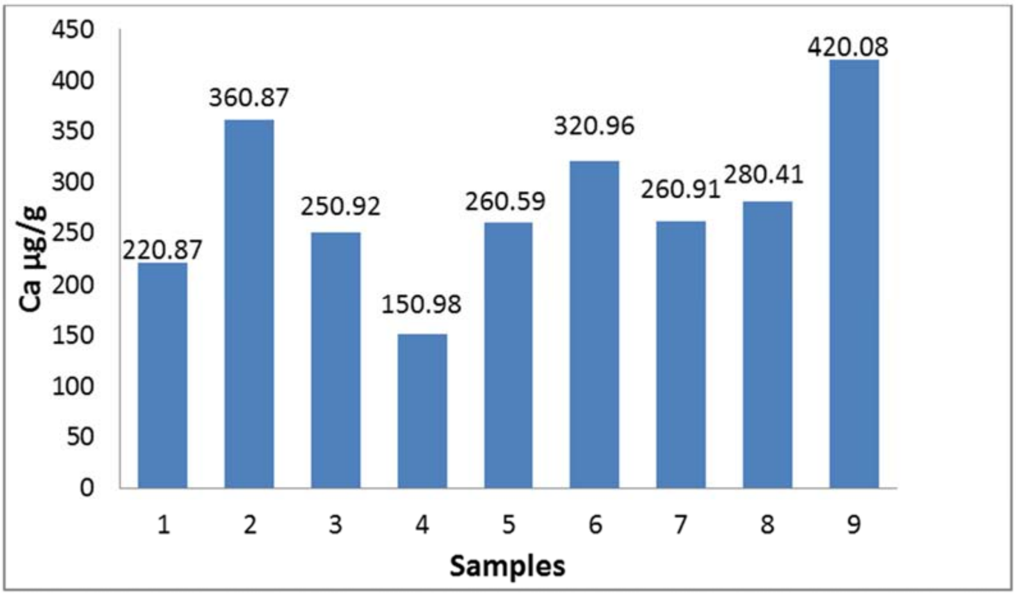

Figure 9. *Distribution of Calcium in baby food Samples.*

The highest content of macro-element present in all samples of baby food was Sodium and it ranged from 150.98 to 670.91 µg.g^{-1}, with a mean of 381.95 µg.g^{1}as seen in Figure. (10). Baby food contains sodium (the water and added sodium salts such as benzoates, citrates or saccharin).

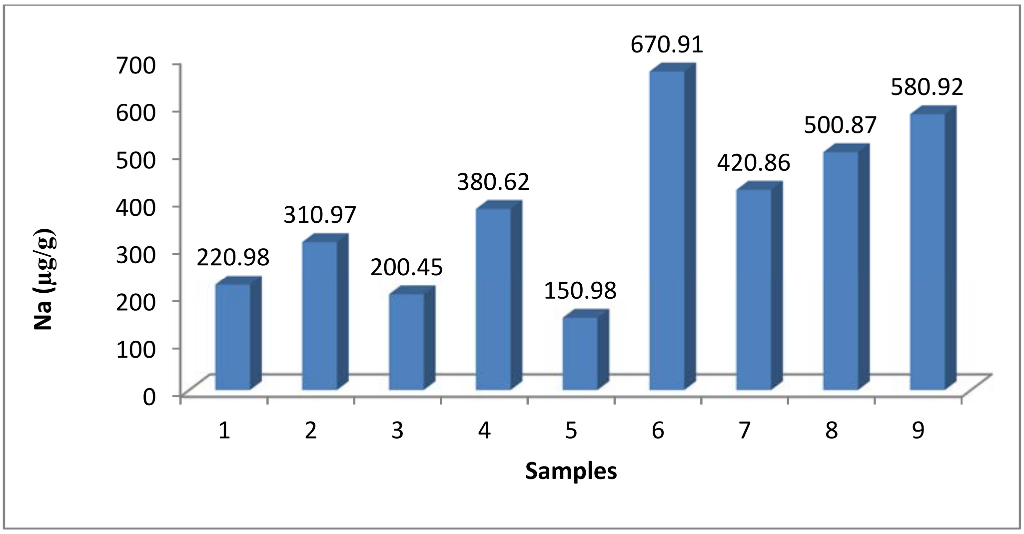

Figure 10. *Distribution of Sodium in baby food Samples.*

Potassium is the most abundant intracellular ion, and it is essential for membrane transport, energy metabolism and normal functioning of cells. Potassium is found naturally in the fruit in the form of potassium salts of tartaric acid. The level of potassium in baby food ranged from 90.41 to 360.85 µg. g^{-1}, the highest content of potassium was in sample (9) and the lowest content was in the sample (2). Our study showed statistical significance (p <0.05)) difference in content of K for tasted baby food, that indicate that all baby food had different content of this element. In regard of this finding, every type of baby food can have different nutritional value for human diet, according to the content of potassium.

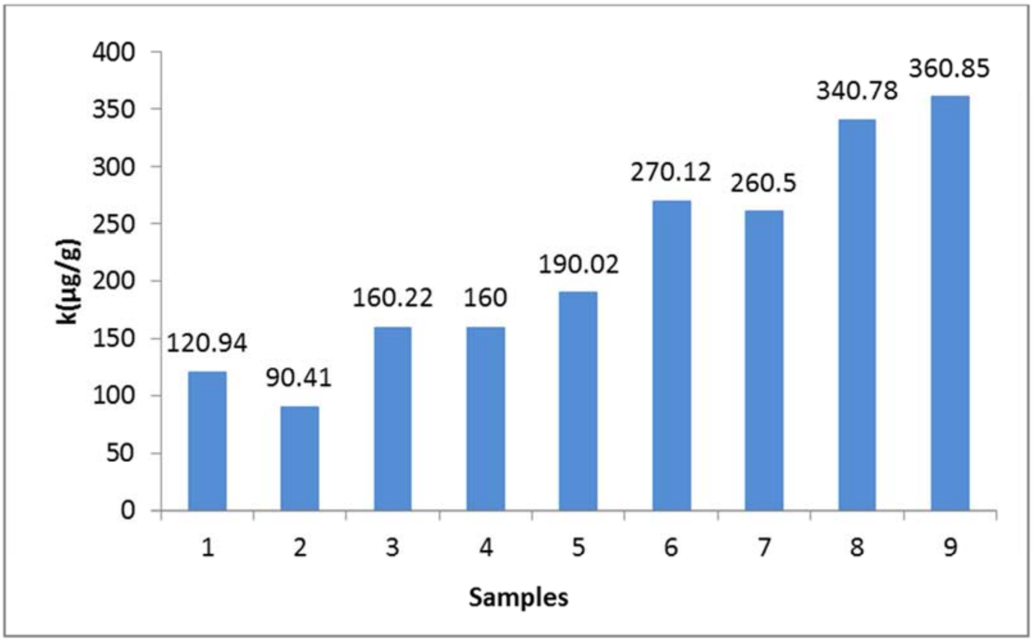

Figure 11. *Distribution of Potassium in baby food Samples.*

4. Conclusion

The analysis of these samples shows that the samples are adequate in some essential trace elements as well as some of the non-essential trace elements. These trace elements are particularly significant as these foods are used as supplements to regular breast-feeding. For the elements found in this study, the concentrations of the essential trace elements compared well with that of other researchers and are within the limit specified in international guidelines.

The toxicity of some of the non-essential trace elements in all the samples is well below known toxicity limits. Notwithstanding, there is a need for baby food manufacturers and suppliers in Libya to continue to make every effort to reduce the toxic elements concentration in their products.

The results of our work shows that infant baby food products produced in Libya is adequate in both essential and non essential trace elements and the toxic elements are within safety limits. Therefore, infant food produced in Libya can serve adequately as complementary food for infants. Also, the concentrations of these elements are within the safe limit for infants as compared with recommended values by WHO/UNICEF, among others.

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