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Analytical Methods

Bioavailability of Fe and Zn in selected legumes, cereals, meat and milk products consumed in Fiji

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ABSTRACT

The present study reports contents and the bioavailability of Fe and Zn from 25 selected raw and cooked food samples. The results showed highest variation of Fe content in raw food samples ranging from 2.19 ± 0.04 to 0.93 ± 0.03 mg/100 g in legumes. The raw black eye bean, cheese and fish showed high Zn content up to 8.85 ± 0.01, 12.93 ± 0.26 and 172.03 ± 5.09 mg/100 g, respectively. Pulses and cereals showed high level of ionizable Fe. Zn bioavailability was quite low in cereals as compared to pulses; 4.02% in yellow split to 17.40% in Bengal gram. Zn bioavailability of 17.40% is in cheese. Fe bioavailability is high in cooked rice 160.60%, white bread 428.30% and milk powder 241.67% showing that Fe bioavailability increased after cooking whereas the lowest in fish 0.84%. The multivariate and cluster analysis categorized studied foods into two main groups.

1. Introduction

Food plays an important role in human health. The human body gets essential minerals from foods which are required in varying amounts to regulate physiological needs. The minerals and vitamins that are required in milligram or microgram amounts daily by human body are called micronutrients. The World Health Organisation (WHO, 2000) report shows that globally half a billion women in reproductive age are affected by anemia and micronutrient deficiencies. In developing countries, cereals and pulses/legumes are used as staple foods and are good source of micronutrients. However, low consumption of micronutrients has been reported to be the main cause of mineral deficiency which includes iron and zinc, among majority of Fiji's population (Harvey & Vatucawaqa, 2007). It has also been reported that Fiji is facing an anemia problem since 1940 (Harvey & Vatucawaqa, 2007). Report by Harvey and Vatucawaqa (2007) showed that 33–40% children and women were anemic out of which about 37% were multiple micronutrients deficient.

Iron (Fe) and Zinc (Zn) are two important trace minerals which are easily available in food sources. Trace element iron is mainly present in the blood as hemoglobin and in muscle tissue as myoglobin. Thus, iron has a vital role as an oxygen carrier in the blood and is also involved in DNA synthesis, energy production and metabolic processes. Daily requirement of iron depends on age, sex, and the weight of individuals (USDA). Fe is found in foods in two forms; heme and non heme iron. The heme iron is more bioavailable than the non heme (Moorsell, 1997). Poultry, fish, meat, cereals, green leafy vegetables, grains fruits and other vegetables are good sources of Fe (Whitney & Rolfes, 2012, chap. 13). Body's mechanism maintains the Fe balance through stores, reutilizes and regulates in the body (Whitney & Rolfes, 2012, chap. 13).

Zn is another essential trace mineral which is required by the human body as it has significant role in cell growth and replication, bone formation, skin integrity, immune system function and sexual maturation (Etcheverry, Grusak, & Fleige, 2012; Sandberg, 2005). Dietary sources of Zn are dried beans, seeds, animal products like meat, eggs, cheese, etc. Chronic Zn deficiency damages human's central nervous system and brain which affects the cognitive and motor development (Whitney & Rolfes, 2012, chap. 13). In addition, higher incidences of motility in infant and child, respiratory tract pneumonia, diarrhoea, child stunting, etc. have been caused by Zn deficiency (Barnett, Hamer, & Meydani, 2010; Luabeya et al., 2007).

The World Bank development report 1993 suggested three cost effective micronutrient malnutrition management strategies; Fortification (addition of an ingredient to food to increase the content

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of a particular element), Enrichment and Supplementation (World Development Report, 1993). Fiji went ahead with fortification of wheat flour according to WHO standards (Schuitz & Vatucawaqa, 2012). Food and Nutrition Department and Ministry of Health, Government of Fiji, has been working towards controlling the mineral deficiencies through food fortification and tablet distribution programme in schools (Schuitz & Vatucawaqa, 2012). However, there is dearth of information on the bioavailability of trace elements from various food samples consumed in Fiji and has not at all been studied. The bioavailability has been studied either using *in vivo* (involve humans or animals) or in *vitro* (stimulated condition) methods (Fairweather-Tait, 1987). However, food content has many soluble and insoluble complexes which can affect minerals absorption *i.e.,* bioavailability in the body. The modifications in diet can improve the bioavailability of minerals. The bioavailability of mineral elements can also be improved by increasing dietary factors that enhance mineral absorption in the intestine. Some natural chelating agents also play a key role in the solubilization of food minerals and trace elements (Ekholm, Virkki, Ylinen, Johansson, & Varo, 2000; Hazell & Johnson, 1987; Miller, Schricker, Ramussen, & Van Campen, 1981).

We have been interested in enhancing foods intake for optimal nutrition and food security in the South Pacific thereby popularizing the consumption of local foods (Roshni, Prasad, & Bhati, 2014). We have reported the determination of the nitrate contents in commonly consumed fresh, cooked and frozen leafy, root and fruit vegetables marketed in Fiji (Chetty & Prasad, 2009; Prasad & Chetty, 2008, 2011). The most recently we have also reported the retention of folate contents in vegetables upon different methods of cooking (Maharaj, Prasad, Devi, & Gopalan, 2015). Therefore, in continuation of our study on Fijian foods (Chetty & Prasad, 2009; Maharaj et al., 2015; Prasad & Chetty, 2008, 2011; Roshni et al., 2014) and given the fact that the bioavailability of commonly consumed foods in Fiji has not at all been studied, the present study was initiated with the objective to determine the total content of Fe and Zn and their bioavailability in the most commonly consumed Fijian foods.

2. Materials and methods

2.1. Food samples

A total of 25 food samples were selected from the different food groups such as cereals, (long grain rice, brown rice (*Oryza sativa*), white bread, whole meal bread (Triticum), weet-bix, oats (*Avena sativa*) and flours), pulses (yellow split, black eye beans (*Vigna unguiculata subsp. unguiculata)*, chick peas (*Cicer arietinum*), green gram/moong whole (*Vigna radiata*), Bengal gram/Chana dal (*Cicer arietinum*), toor dal/spilt red gram (*Cajanus cajan*), blue peas (*Pisum sativum*) and red kidney beans (*Phaseolus vulgaris*), meat (chicken breast (*Gallus gallus domesticus*), lamb chops (*Ovis aries*) and fish (*Thunnini*)) and dairy products (milk powders and cheese). These food samples were collected from different supermarkets in Suva, Fiji. The food samples were powdered using Panasonic mixer grinder and passed through 500 μm sieve. The bread samples were dried in an oven (Contherm, New Zealand) at 80 °C for 2 h and then powdered and sieved. The food samples like meat, fish and cheese were freeze dried, powdered and then sieved. All the food samples thus prepared were kept in the air tight containers in desiccators till the analysis was carried out.

2.2. Apparatus

Muffle furnace (Carbolite, OWF1100) was used to white ash the dried food samples. A freeze dryer (Dynavac Engineering freeze-dryer) was used for drying the food samples like meat, dairy products and homogenized before making them powder. A Panasonic mixer and grinder (MX119N) was used to grind the food samples. A shaker water bath (Labec, Laboratory Equipment Pvt. Ltd., Australia) was used to incubate all samples. A Perkin Elmer 400 atomic absorption spectrophotometer (AAS) was used to determine the levels as well as bioavailability of Fe and Zn in selected food samples. A pH meter (pH700, Eutech-Instruments, Singapore) was used to adjust the pH of the sample solutions. All the glassware were scrupulously washed with the detergent, rinsed thoroughly with tap water and soaked in 10% nitric acid bath for 48 h to remove any contamination. Soaked glassware were rinsed with the distilled deionized water (DDW) and dried.

2.3. Reagents and standards

All the reagents used were of analytical reagent grade. All aqueous solutions were prepared in distilled de-ionized ultra-pure water (Millipore 18 MΩ cm). The standard stock solution of Fe (1000 mg/L) was prepared using ferric chloride ($FeCl_3 \cdot 6H_2O$) from Loba Chemie, India and stored in amber reagent bottle. The zinc metal powder (BDH Chemicals Ltd., England) was used to prepare its 1000 mg/L standard stock solution. Then serial dilutions were made to obtain the standard concentrations according to the linear calibration range of AAS. The acids, HCl (37%) and HNO_3 (70%) were purchased from Sigma–Aldrich, Australia. The pepsin–HCl solution (0.5%) was freshly prepared using 0.5 g of pepsin (Sigma–Aldrich) in 100 mL 0.1 M HCl. The pH of trypsin (Loba Chemie, India) 5 mg/g of sample was adjusted to 7.5 using 10% sodium hydroxide solution (Loba Chemie, India). The standard buffers (Sigma–Aldrich) of pH 4 and 7 were used to standardize the pH meter before its use.

2.4. Sample preparation

2.4.1. Dry ashing

All the dry food samples were ground using Panasonic mixer and grinder (MX 119N). 10 g of each food samples were weighed in triplicate and placed in a previously weighed porcelain crucible and heated to 550 °C in muffle furnaces for 10 h leading to white ash. The white ash samples were reweighed, dissolved in 6 mL concentrated HNO_3 and diluted to 50 mL in calibrated volumetric flasks with DDW. The solutions thus obtained were used to determine the total content of Fe and Zn using AAS.

2.4.2. Determination of ionizable iron and bioavailability

The selected food samples were digested following a simulated *in vitro* gastrointestinal digestion technique. The triplicate samples of 2 g powdered/homogenized raw or cooked were taken in centrifuge tubes and 25 mL of 0.5% pepsin–HCl acid solution was added to each. The content in the each centrifuge tube was adjusted to pH 1.35 using 1% HCl solution and incubated at 37 °C in a shaker water bath for 90 min. After the incubation, the pH of the samples was slowly adjusted to 7.5 using 20% NaOH. This was followed by addition of trypsin (5 mg/g of sample) to the flask's content and incubated for further 90 min under the same conditions as done with pepsin *i.e.*, 37 °C. The contents were centrifuged at 9000 rpm for 30 min. The supernatants were collected for *in vitro* determination of ionizable Fe and Zn using AAS and thus their bioavailability. The bioavailability (%) of Fe and Zn in the food samples was calculated using equation shown below (Hemalatha, Platel, & Srinivasan, 2007; Rao & Prabhavathi, 1978).

$$\text{Bioavailability}\ (\%) = \frac{\text{The fraction of the element } in\ vitro \text{ digested sample}\left(\frac{\text{mg}}{100\,\text{g}}\right)}{\text{The total content of mineral element}\left(\frac{\text{mg}}{100\,\text{g}}\right)} \times 100$$

2.4.3. Quality control

To avoid contamination disposable gloves were worn throughout the analysis. The glassware was cleaned in 10% HNO_3 bath and samples were stored in plastic storage containers. The samples were analyzed in batches where standard addition method was also used to judge the recovery of the analysis. The calibration standards were used to monitor linearity. The 'in house' reference material at the end of each batch of samples was analyzed to verify the trueness of the method. Triplicate samples were used for precision and reproducibility of the results.

3. Results and discussion

Information on bioavailability of minerals from commonly consumed food is not at all available in Fiji. Therefore, it was extremely essential to know the bioavailability of selected elements in the natural food ingredients or mineral sources that are used as dietary supplements in the Pacific region (WHO, 2000). A total of 25 different food samples were analyzed and the results have been discussed in the following sections.

3.1. Total iron and zinc

The total contents of Fe and Zn determined in the raw food samples are given in Table 1. The Fe contents in raw food samples of cereals ranged from 0.10 ± 0.03 mg/100 g to 2.89 ± 0.27 mg/100 g and Zn 3.23 ± 0.07 mg/100 g to 9.27 ± 0.00 mg/100 g. Similar results for total Fe in whole meal bread 0.6 mg/100 g was reported by Pacific Island Food Composition Table (Dignan, Burlingame, Kumar, & Aalsbersberg, 2004). The pulses and legumes (yellow split, black eye beans, chick peas, green gram (moong whole), Bengal gram, toor dal (split red gram), blue peas and red kidney beans) showed the Fe contents ranging from 0.93 ± 0.00 mg/100 g to 2.19 ± 0.04 mg/100 g while Zn ranging 5.15 ± 0.26 mg/100 g to 8.85 ± 0.01 mg/100 g. A comparison of Fe and Zn contents reported in literature for few food samples is shown in Table 1. The Fe content is low in pulses and legumes and Zn is high in the current study as compared to few reported values shown in Table 1. The dairy products (milk powders and cheese) have low Fe and Zn contents as compared to cereals and pulses. Similar results have been reported in literature (Khalil & Seliem, 2013; Villapando, Shamah, Rivera, Lara, & Monterrubio, 2006). The milk powder (three different brands) showed Fe content in the range 0.34 ± 0.17–0.12 ± 0.00 mg/100 g whereas Zn content ranged 4.99 ± 0.22–5.70 ± 0.00 mg/100 g. The reported Fe content in milk powder is 0.3 mg/100 g (Dignan et al., 2004) whereas the current study showed 0.34 ± 0.17 mg/100 g Fe but Zn is high in current study. The meat products showed high value of Fe as well as Zn contents in raw food samples. The Fe content in chicken breast is 1.66 ± 0.00 mg/100 g and Zn is 3.13 ± 1.32 mg/100 g whereas lamb chops showed 2.21 ± 0.39 mg/100 g Fe and 4.01 ± 0.43 mg/100 g, Zn. The literature values for Fe and Zn contents in lamb chops are close to the values found in current study but Fe and Zn contents in tuna fish showed significant difference. The tuna fish showed the highest content of Fe 41.46 ± 0.06 mg/100 g and Zn 172.03 ± 5.09 mg/100 g which are more than a daily requirement (USDA, Dietary reference intakes).

The whole meal flour fortified with Fe and Zn showed higher Fe and Zn contents as 2.35 ± 0.20 mg/100 g and 7.19 ± 0.26 mg/100 g, respectively. However, roti atta (flour) had less Fe 0.62 ± 0.17 mg/100 g but showed the highest Zn content

Table 1
Comparison of current results and literature values of total iron and zinc contents in selected raw (dry) food samples.

Current study			Literature values		
Food sample	Iron (mg/100 g)	Zinc (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	References
Long grain rice (white)	0.10 ± 0.03	3.23 ± 0.07	NA	NA	–
Brown rice	0.20 ± 0.03	4.11 ± 0.00	NA	NA	–
Whole meal bread	0.62 ± 0.03	9.12 ± 0.18	0.6	0.4	Dignan et al. (2004)
White bread	0.53 ± 0.10	8.25 ± 0.88	NA	NA	–
Weet-bix	2.89 ± 0.27	4.69 ± 0.03	0.6	2.6	Dignan et al. (2004)
Oats (rolled)	1.24 ± 0.03	4.74 ± 0.00	NA	NA	–
Normal flour (Punjas)	0.65 ± 0.00	7.84 ± 0.20	NA	NA	–
Yellow split	1.52 ± 0.03	5.49 ± 0.15	NA	NA	–
Black eye bean	1.77 ± 0.04	8.85 ± 0.01	NA	NA	–
Chick peas	1.34 ± 0.10	6.30 ± 0.07	13.4	3.35	Abebe et al. (2007)
			4.95 ± 0.12	2.03 ± 0.09	Hemalatha et al. (2007)
Green gram (moong whole)	1.41 ± 0.00	6.17 ± 0.10	4.55 ± 0.13	2.40 ± 0.07	Hemalatha et al. (2007)
			6.12 ± 0.30	NA	Das, Raghuramulu, and Rao (2005)
			9.2	3.4	Dignan et al. (2004)
Bengal gram (chana dal)	1.77 ± 0.04	7.07 ± 0.17	5.62 ± 0.40	NA	Das et al. (2005)
Split red gram (toor dal)	0.93 ± 0.00	5.15 ± 0.26	4.93 ± 0.05	2.35 ± 0.2	Hemalatha et al. (2007)
			3.62 ± 0.12	NA	Das et al. (2005)
Blue peas	1.67 ± 0.03	6.82 ± 0.03	5.0	4.13	Abebe et al. (2007)
Red kidney beans (rajma)	2.19 ± 0.04	6.57 ± 0.08	12.2	4.75	Abebe et al. (2007)
			6.36	NA	Das et al. (2005)
Normal flour (fmf)	1.38 ± 0.39	7.63 ± 1.28	NA	NA	–
Roti atta (fmf)	0.62 ± 0.17	9.27 ± 0.00	NA	NA	–
Wholemeal flour	2.35 ± 0.20	7.19 ± 0.26	NA	NA	–
Milk powder (red cow)	0.34 ± 0.17	4.99 ± 0.22	0.3	2.8	Dignan et al. (2004)
Milk powder (Punjas)	0.12 ± 0.00	5.98 ± 0.12	NA	NA	–
Milk powder (rewa)	0.12 ± 0.00	5.70 ± 0.00	NA	NA	–
Cheese pizza (rewa)	1.52 ± 0.20	12.93 ± 0.26	NA	NA	–
Chicken breast	1.66 ± 0.00	3.13 ± 1.32	NA	NA	–
Lamb pieces (chops)	2.21 ± 0.39	4.01 ± 0.43	1.8	3.5	Dignan et al. (2004)
Fish (tin tuna)	41.46 ± 0.06	172.03 ± 5.09	0.6	0.8	Dignan et al. (2004)

Results are presented as mean ± SD of triplicate determinations.
NA; not available.
fmf: Flour Mills of Fiji Limited.

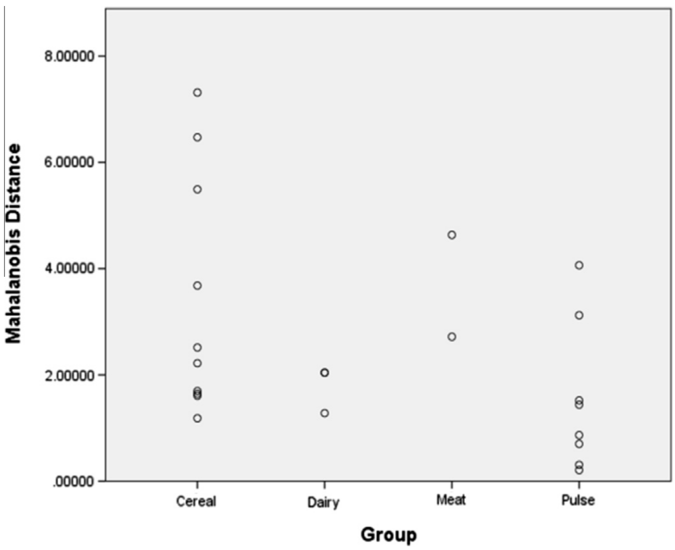

Fig. 1. Multivariate analysis of food samples (cereals, dairy, meat and pulses) using Mahalanobis distances.

9.27 ± 0.00 mg/100 g. The normal flour showed higher Fe content 1.38 ± 0.39 mg/100 g than roti flour but roti flour had quite high Zn content as 9.27 ± 0.00 mg/100 g. In Fiji, people use normal flour much more as compared to whole meal flour. The survey report conducted in 2010 by Fiji National Food and Nutrition Center, showed positive improvement in Zn and Fe deficiency rate and anemia after implementation of the fortified flour program in Fiji which is in line with our finding where the maximum used normal flour has relatively high Fe content (Schultz & Vatucawaqa, 2012). Most of the results from the studied food samples (Table 1) showed less Fe and Zn contents than reported in literature (Ekholm et al., 2000; Hemalatha et al., 2007). The possible reasons of this difference could be different methods and sample selection, climatic conditions, use of fertilizers, type of soil and storage and processing of food (Mayer, 1997; Reddy & Love, 1999).

Fig. 1 shows the outliers from the multivariate analysis identified using Mahalanobis distance which is the distance of each sample group from the mean center where cheese and fish with very high content of Zn 12.93 ± 0.26 and 172.03 ± 5.09 mg/100 g became outliers. Thus, fish and cheese with high Fe and Zn contents are very different from the other food samples. The multivariate analysis of studied food samples shows, how similar are the food samples with respect to their mineral (Fe and Zn) contents. This study quantitatively confirmed that the foods with close values of mineral contents are good source of minerals from each food group *i.e.* cereals, pulses and legumes, dairy and meat.

3.2. Cluster analysis

For the cluster analysis of the food types, Hierarchical method was used in which Ward's method and Euclidian distance was used to create dendrograms where the height of cluster clades shows the distance between two data points or indicates similarity or difference between them. Fig. 2 clearly shows that the cluster forms two groups: one for cereals and milk powders (whole meal bread to milk powder) while the second is for meat and pulses (chicken to red kidney beans). The food samples which have low contents

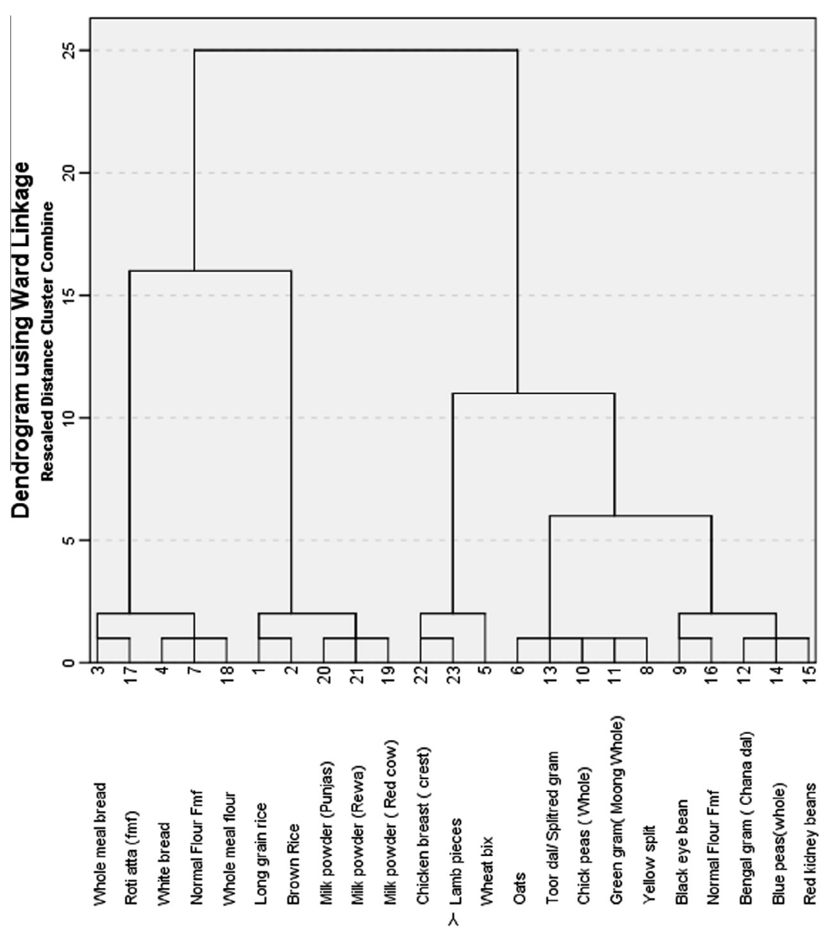

Fig. 2. Dendrogram of cluster analysis (Ward's method) for mineral contents in selected raw food samples (mg/100 g).

of Fe and high content of Zn are in one cluster *i.e.,* cereals and milk powders. On the other hand, the food samples which have high contents of Fe and Zn fall in other cluster. The food samples with similar contents of Fe and Zn made one clade (whole meal bread Fe/Zn 0.62 ± 0.03/9.12 ± 0.18 mg/100 g, roti flour, 0.62 ± 0.17/9.27 ± 0.00 mg/100 g). White bread Fe/Zn 0.53 ± 0.10/8.25 ± 0.88 mg/100 g, normal flour (Punjas) 0.65 ± 0.00/7.84 ± 0.20 mg/100 g and whole meal flour 2.35 ± 0.20/7.19 ± 0.26 mg/100 g fall into one clade as their Fe and Zn contents are quite close. Rice and different brand milk powders made one clade because their Fe/Zn contents ranged between 0.10 ± 0.03/3.23 ± 0.07 mg/100 g and 0.34 ± 0.17/4.99 ± 0.22 mg/100 g. Oats, toor dal (split red gram), chick peas, green gram (moong whole) and yellow split have made one clade with Fe/Zn content 1.24 ± 0.03/4.74 ± 0.00, 0.93 ± 0.00/5.15 ± 0.26 mg/100 g, 1.34 ± 0.10/6.30 ± 0.07 mg/100 g, 1.41 ± 0.00/6.17 ± 0.10 mg/100 g and 1.52 ± 0.03/5.49 ± 0.15 mg/100 g, respectively (*cf*. Fig. 2).

3.3. Iron and zinc bioavailability

The bioavailability of Fe and Zn was determined using *in vitro* digestibility method in all selected samples of four different food groups and the results are presented in Table 2. The fortified foods such as white bread and whole meal bread showed very high Fe bioavailability of 428.30% and 269.35%, respectively. The pulses/legumes, in general, showed lower bioavailability of Fe and Zn due to presence of phytate (Sandberg, 2002). Thus Fe bioavailability in pulses/legumes ranged from 14.47% to 32.26% (yellow split and toor dal) and Zn from 4.02% to 17.40% (yellow split and Bengal gram). In pulses/legumes, the chick peas and toor dal have high Fe bioavailability of 20.90% and 32.26%, respectively. Among pulses, Zn showed the highest bioavailability in Bengal gram as 17.40%. The bioavailability of Fe in the chick peas is higher in current study (20.90%) than reported (6.89%) by Hemalatha et al. (2007). Among all the foods studied fortified white bread (cereals) showed the highest bioavailability of Fe as 428.30%. Fe bioavailability in the milk products varied from 25.66 to 241.67% while Zn bioavailability was in the range of 15.38–17.40%. The meat products showed Fe bioavailability of 0.84% in fish to 14.47% in chicken and Zn bioavailability of 0.08% and 4.87%, respectively. However, the bioavailability of Zn in lamb chops is the highest (56.35%) among the meat products.

Fig. 3 presents a comparison of the bioavailability of Fe and Zn in different food groups *i.e.* cereals, pulses/legumes, meat and dairy products. Fig. 3A clearly shows that the highest bioavailability of Fe is in toor dal and lowest in yellow split while Bengal gram shows the highest bioavailability of Zn and the least in yellow split. Under the meat food group (Fig. 3B), lamb chops shows the highest Zn bioavailability while chicken breast shows the highest Fe bioavailability. Cereals demonstrate the decreasing trend of Fe bioavailability from long grain rice to normal flour (Fig. 3C) while Zn bioavailability corresponding in cereals is much less (Fig. 3C). In general, higher Fe bioavailability was found in cereals as compared to Zn.

It has been reported that high protein diets and their combination with ascorbic acid increase the bioavailability of Fe (Diaz, Rosado, Allen, Abrams, & Garcia, 2003; Lynch & Cook, 1980). It has also been reported that the heat treatment to the food samples has significant impact on the bioavailability of minerals content. In general, raw food products have high content of minerals compared to cooked products (Norhaizan & Nor, 2009). Zn bioavailability reduced while iron bioaccessibility increased after cooking (Hemalatha et al., 2007; Lee & Clydesdale, 1981). Among the selected food groups between cereals and pulses, cereals showed high bioavailability compared to pulses/legumes. The bioavailability of Zn in all studied foods in the present case is low in

Table 2
Determination of ionizable iron and zinc and their bioavailability in the selected food samples.

Sample	Ionizable iron (mg/100 g)	Ionizable zinc (mg/100 g)	Iron Bioavailability (%)	Zinc Bioavailability (%)
Cereals				
Long grain rice (white)	0.28 ± 0.06	0.18 ± 0.04	160.60 ± 0.03	13.62 ± 0.07
Brown rice	0.12 ± 0.00	0.14 ± 0.00	85 ± 0.00	7.30 ± 0.00
Whole meal bread	1.67 ± 0.02	0.46 ± 0.01	269.35 ± 0.02	5.04 ± 0.18
White bread	2.27 ± 0.11	0.95 ± 0.03	428.30 ± 0.11	11.52 ± 0.88
Weet-bix	0.41 ± 0.04	0.02 ± 0.01	14.19 ± 0.04	0.43 ± 0.03
Oats (rolled)	0.10 ± 0.02	0.11 ± 0.04	12.10 ± 0.03	4.64 ± 0.00
Normal flour (Punjas)	0.36 ± 0.02	0.05 ± 0.00	55.38 ± 0.05	0.64 ± 0.64
Normal flour (fmf)	0.10 ± 0.02	0.07 ± 0.00	7.25 ± 0.02	0.86 ± 1.28
Roti atta (fmf)	0.08 ± 0.00	0.06 ± 0.00	12.90 ± 0.00	0.65 ± 0.00
Whole meal flour	0.12 ± 0.08	0.04 ± 0.00	16.67 ± 0.08	0.56 ± 0.26
Pulses/legumes				
Yellow split	1.28 ± 0.07	1.01 ± 0.00	14.47 ± 0.03	4.02 ± 0.15
Black eye bean	1.26 ± 0.06	1.02 ± 0.06	16.38 ± 0.04	8.70 ± 0.01
Chick peas	2.07 ± 0.06	1.01 ± 0.01	20.90 ± 0.10	11.43 ± 0.07
Green gram (moong whole)	0.78 ± 0.07	0.68 ± 0.01	18.44 ± 0.00	12.48 ± 0.10
Bengal gram (chana dal)	0.81 ± 0.00	0.61 ± 0.00	21.47 ± 0.04	17.40 ± 0.17
Toor dal (split red gram)	1.25 ± 0.02	0.91 ± 0.01	32.26 ± 0.00	13.20 ± 0.26
Blue peas	1.34 ± 0.02	1.11 ± 0.03	18.56 ± 0.03	15.54 ± 0.03
Red Kidney beans (rajma)	1.68 ± 0.17	0.88 ± 0.02	15.53 ± 0.04	15.83 ± 0.08
Dairy products				
Milk powder (red cow)	0.29 ± 0.00	0.85 ± 0.07	85.29 ± 0.00	17.03 ± 0.22
Milk powder (Punjas)	0.29 ± 0.00	0.92 ± 0.03	241.67 ± 0.00	15.38 ± 0.12
Milk powder (rewa)	0.25 ± 0.04	0.92 ± 0.07	208.33 ± 0.04	16.14 ± 0.00
Cheese pizza (rewa)	0.39 ± 0.02	2.25 ± 0.06	25.66 ± 0.02	17.40 ± 1.32
Meat products				
Chicken breast	0.45 ± 0.00	0.17 ± 0.00	14.47 ± 0.00	4.87 ± 0.26
Lamb chops	0.43 ± 0.14	0.78 ± 0.14	9.05 ± 0.00	56.36 ± 0.43
Fish (tin tuna)	0.35 ± 0.02	0.13 ± 0.02	0.84 ± 0.02	0.08 ± 5.09

Results are presented as mean ± SD of triplicate determinations.
fmf: Flour Mills of Fiji Limited.

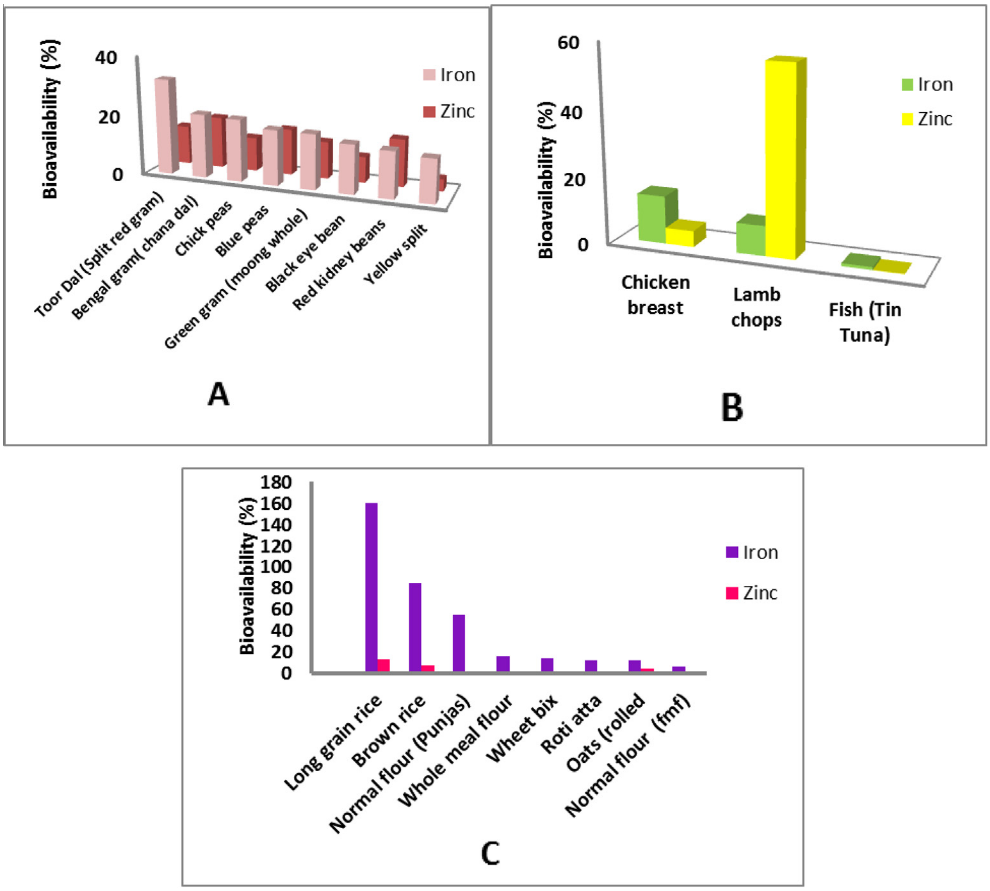

Fig. 3. A comparison of the bioavailability of Fe and Zn in different food groups: (A) pulses/legumes, (B) meat products and (C) cereals.

comparison to the bioavailability of Fe whereas Zn content is generally high in raw foods in comparison to Fe. This may be due to the presence of phytate, tannin, etc. in the food samples. The bioavailability of Zn in long grain rice is 13.62%, whole meal bread 5.04%, white bread 11.52%, roti flour 0.65%, milk powders 17.03%, 15.38% and 16.14%. The total content of Fe and Zn and Zn bioavailability of rice is lower than reported by Hemalatha et al. (2007) and Norhaizan and Nor (2009). Phytate content in cereals and cooking method have significant influence on Fe and Zn bioavailability (Larsson, Rossander-Hulthen, Sandstrom, & Sandberg, 1996). Studies have shown that there are many factors which affect minerals bioavailability from food samples (Bartnik & Szafranska, 1987; Carlos, Ayala-Zavala, & Gonzalez-Aguilar, 2011; Marfo, Simpson, Idowu, & Oke, 1990). These factors are soil composition where food was grown, climatic conditions, mineral content of soil, storage, ripping system and cooking methods of foods (Hefnawy, 2011; Mayer, 1997; Wang, Hatcher, Toews, & Gawalko, 2009).

4. Conclusions

The present study reports the total content of Fe and Zn in raw food samples and their bioavailability in the food samples which are commonly consumed by Fiji population. The total Fe and Zn content is high in pulses as compared to other foods but cereals showed higher bioavailability than the pulses. The absorption of Fe and Zn mineral from foods depends on their contents and other factors (phytate, tannin, etc.) available in the food samples. Cooking processes affect the Fe and Zn content in foods whereas variable results on bioavailability have been shown.

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