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RESEARCH ARTICLE :

Bio availability of iron from finger millet, pearl millet and rice (control) recipes

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SUMMARY : The present study entitled ''Bioavailability of iron from finger and pearl millet based recipes'' was conducted on four millet preparations namely dosa, idli, roti and rice (meal), using two millets namely finger millet, pearl millet. The iron content of millets was 3.65, 7.0mgin finger millet, pearl millet, respectively. Compared to rice all millets had high amount of protein, fat, ash and iron content, while the carbohydrate was low in millets compared to rice. Wheat had similar protein, fat and carbohydrates close to many types of millet.The total iron was good in all preparations.Finger millet idli had 4.57mg and meal had 4.58mg total iron without any significant difference between the two products.The dosa had a total iron of 5.04mg and roti had 5.55mg both of which differed significantly compared to each other and with other preparations ($p<0.05$). Per cent available iron was highest in finger millet dosa at 37.3% against 4.1% in idli, 12.3% in roti and 2.7% in meal with significant difference between each other ($p<0.05$).Per cent available iron was highest in pearl millet dosa at 62.4%against in 33.5% in idly, 44.0% in roti and 44.0% in meal. Total iron content was 7.9mg in rice dosa, which was highest, followed by 4.8mg in roti, 3.8mg in meal and 1.8mg in idli, with significant difference between preparations ($p<0.05$).Per cent available iron was least in roti at 5.2% against meal at 8.2%, idli at 6.59% and dosa at 25.6% with significant difference between each other. Percent available iron was least in roti at 5.2% against meal at 8.2%, idli at 6.59% and dosa at 25.6% with significant difference between each other. The *in vitro* availability of iron was high in dosa, probably due to fermentation and shallow fry on iron tawa, seems to low steamed cooking method of pearl millet idly compared to dry heat or roasted millet preparations.

KEY WORDS:
Bioavailability of iron, Finger millet, Pearl millet, Rice

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BACKGROUND AND OBJECTIVES

The name millet is applied to numerous small seeded grasses which originated in Asia or Africa. Millets include five Genera, Panicum, Setaria, Echinochloa, Pennisetum, and Paspalum. The most important cultivated species of millets are pearl or cattail millet (*Pennisetum glaucum*), fingermillet (*Eleusine coracana*), little millet. Various millets grown in India are finger millet (*Eleusine coracana*) and little millet (*Panicum milliare*)and sorghum (*Sorghum vulgare*). The bioavailability of iron in a meal is the result of several known and unknown

dietary factors. There are two kinds of iron compounds in the diet with respect to the mechanism of absorption heme iron (derived from haemoglobin and myoglobin) and non-heme iron (derived mainly from cereals, fruits, and vegetables). The absorption of these two kinds of iron is influenced differently by dietary factors. Heine iron forms a relatively minor part of iron intake. Even in diets with a high meatcontent it accounts for only 10-15%of the total iron intake.

RESOURCES AND METHODS

In this study selected millets and rice made into products such as dosa, idly, *Roti* and meal, proximate analysis and iron availability done following standardmethods.

Sample preparation :

Finger millet, pearlmillets were procured from Grameen mall Foundation,it is a NGO, from Hyderabad encouraging farmers to cultivate all varieties of millets and facilitate the farmers to process millets and sell them. The other ingredients used for preparation of millet recipes, like blackgram dal, rice, wheat flour, idli rava, oil and salt were obtained from local market.

The selected millets namely finger millet, pearl millet, were processed and developed into two meal items *i.e* millet rice and *Roti* and two breakfast items namely idly and dosa. As control rice was used for idli, dosa, boiled rice and wheat was used for making *Roti*. Basic standard preparations procedures were followed for all millet preparations. The grains were soaked 2hrs pearl millet and finger millet and cooked with double the quantity of water for 7-10 minutes in open/pressure cooking to a soft meal. Rice (*Oryza sativa*) was used as control, which was also cooked by the same standard method.To each of 50g millet flour a pinch of salt was added. The flours were made into soft dough by pouring hot water (20-30ml) and kneading well. The dough ball of a big lime size was placed on wooden *Chapati* board and patted with fingers to spread into big, thin *Roti*. The *Roti* was transferred on to a hot tawa, or pan and baked on both sides till done. Each millet idli was prepared by soaking 25g blackgramdal for 4-5hrs and grinding it into a fluffy batter to which each millet semolina soaked for 1 hr (procured from Grameenmall Foundation) was added and batter was left for 6-7hrs fermentation and then added with required salt. The batter was poured in idli moulds and steamed for 7-9 minutes. Idli rava (parboiled rice semolina) was used for control idli samples. Raw millets and black gram dhal were soaked separately for 3-4h and ground separately into fine batter, and mixed together and fermented over night. Salt was added to taste. Dosa was made on hot iron pan by spreading 100ml of batter into a typical round dosa and roasted with little oil dropped on the other circle of dosa.50g millet and 25g blackgram batter gave 2 dosas

In this study proximate analysis was done in millets by standard AOAC methods, iron availability analysis done by (Narsingarao and Prabhavathi,1978).

Statistical analysis:

In this study statistical analysis done was based on correlation between iron availability and two way ANOVA between millet recipes. All the experiments were repeated each with three replicates, and data are presented as means ± standard deviation (SD). Data were subjected for significant difference employing two way analysis of variance (ANOVA) and the means separated using Least Significant Difference (LSD) at less than 1%. Correlation done between available iron and protein, dietary fibre were performed using Microsoft Excel 2007.

OBSERVATIONS AND ANALYSIS

The results obtained from the present study as well as discussions have been summarized under following heads:

Nutrient composition of millets and control (Rice/ Wheat) :

In prepared recipes nutrient analysis done followed standards AOAC methods.

Finger millet and pearl millet and had moisture levels close to each other at 12.8 g,11.8 g, respectively compared rice finger millet had higher value.

Moisture in inappropriate amounts and places is very damaging to the useful life of grain. Once it is reduced to the desired level the grain can then be packaged for storage. Unfortunately, merely reducing moisture content is not always sufficient. Environmental conditions can play a role as well. The propensity of micro-organisms to grow in foods depends on their water content and for this reason many foods are dried below the critical moisture content.

Fat in finger millet with 1.1g, pearl millet with 4.8g

and rice with 0.6, pearl millet had highest fat compared with finger millet and rice. Fat in millets its helps in food softening and matrix, and its give daily requirement of ¼ the requirment for children.

Higher fat content in pearl millet compared to that of foxtail millet was reported by Anbu Malar *et al*. (2015). Food and Agricultural Organization (FAO, 1995) claimed that pearl millet is gluten-free and the total fat content of pearl millet was higher than all of the other millets. It was also reported that pearl millet was quite high in polyunsaturated fats, and that linolenic acid comprised approximately 4% of the fatty acids present

Among millets, finger millet had the lowest protein content of 7.0g/100g and 11.2g with, pearl millet and rice with 0.6g, compared to millets rice had lower protein content.

The higher protein content of millets on par with cereals along with equal energy value makes millets a good substitute for the refined rice or gluten rich wheat, both of which are not recommended for some population with metabolic disorders or those who suffer from gluten enteropathy respectively. In the face of increasing population and stagnant wheat and rice productions, millets are good for those type of diseases and millets can be a promising alternative in solving the problem of food insecurity and malnutrition. Now-a-days children also face constipation problems due to excess eating of refined food through millets based foods reduce that problems and give the minerals and vitamins.

Andrews *et al*. (1996) reported that pearl millet can be 8%-60% higher in crude protein, 40% richer in the amino acids Lysine and methionine, has good levels of Cystine and is 30% richer in threonine. It is regarded as having the highest scores of all the millets when comparing essential amino acids. The essential amino acid profile shows more lysine, threonine, methionine and cystine in pearl millet protein than in proteins of sorghum and other millets pearl millet was slightly richer in protein and fat than foxtail. Proso millet flour can be used a substitute for rice flour in snack foods.

Dietary fibre content of millets :

Among all millets, finger millet had highest content of dietary fibre 11.24g/100g, pearl millet had11.0g/100g compared to rice 0.6g dietary fibre was high in millets.

Consumption of dietary fibre that was viscous lowers blood glucose levels and helps to maintain it and also helps to treat cardiovascular and type II diabetes. Fibres are incompletely or slowly fermented by microflora in the colon promotes normal laxation which prevents constipation, diverticulosis and diverticulitis.

In millets, NSP (non- starchy polysaccharides) form the quantitatively most important source of both soluble and insoluble dietary fibres (Bunzel *et al*., 2001). In cereal botanical components, the majority of dietary fibres generally occur in decreasing amounts from the outer pericarp to the endosperm, except arabinoxylan, which is also a major component of endosperm cell wall materials.

The health benefits associated with high fibre foods are delayed nutrient absorption, increased faecal bulk, lowering of blood lipids, prevention of colon cancer, barrier to digestion, mobility of intestinal contents, increased faecal transit time and fermentability characteristics (Tharanathan and Mahadevamma, 2003).

Ash content of millets :

Ash content of millets finger millet1.1g/100g had lowest and Pearlmillet 2.2g/100g had highest ash content compared with finger millet and rice with 0.8.

Mineral composition of millets :

Millets have high content of minerals are iron, zinc and calcium, highest iron content in pearl millet 9.0mg/100g and finger millet with 3.65mg.

Zinc content in millets highest was found in finger milletwith 2.0mg and Pearl millet with 2.9mg/100g millet rice in 1.2mg/100g.

Calcium content in selected millets decreasing order of calcium, finger millet, millet 342mg/100g and pearl millet 43.6 mg/100g and rice with 9.6mg/100g.

The total iron content varied in the endosperm and bran rich fractions of pearl millet and also among treatments. The bran fraction from germinated grains had significantly (p ¼ 0.05) lesser iron content when compared to untreated bran. The inhibitory factors as well as the iron content were higher in bran rich fraction suggesting that they could be co-located with each other. The seed coat fraction and wheat bran fraction have also been reported to harbour higher minerals like calcium, iron and zinc (Li *et al*., 2015).

High iron content of 28mg/100 g has also been recorded by Bhosale and Vijayalakshmi (2015) in rice bran. Hema *et al*. (2011) reported that iron was more localized in the peripheral region than in the endosperm as evidenced by the fact that decortication for shorter

duration removed 46 to 62% of this mineral

Though finger millet had lower protein content, than other millets and poor when compared to other cereals, it has an extremely high calcium and manganese content, but other minerals and trace elements are comparable to that of sorghum.

Nutrient composition of millet recipes:

In this study four recipes were prepared with millets and calculated nutrient content are protein, dietary fibre and energy and TWO WAY ANOVA done for influence on iron bioavailability in millet recipes.

Protein :

Millet recipes like dosa, idly, *Roti* and meal have different protein content was observed, increased protein content maximum increased in finger products with ranged between 7.7 to 22.6g, protein content in rice 5.4 to 21.5 and pearl millet recipes 10.7 to 26.9 with idly had highest protein compared with ice and finger millet ricepes. available iron significant difference at less than 1% level. Millet recipes have high protein compared to content in rice products.

Dietary fibre :

The dietary fibre content of finger millet recipes ranged between 11.4g to 20.8g,pearl millet recipes 11.0g to 19.7g/100g and control recipes have lowest 3g to 7.6g.

Dietary fibre was high in millet breakfast items idli and dosa, along with control rice based idli, dosa and raw millets inspite of the processing steps like soaking, grinding, fermentation and steaming. Whereas, boiling method and roasting method had slight rise compared to raw samples.

***In vitro* availability of iron from millet recipes:**

In this study selected millet recipes like dosa, idly, *Roti* and meal in these recipes analysis done, in raw millets proximate nutrients and mineral analysis was done. In prepared recipes iron content and available iron analysis were done on dry based.

Iron was analysed by equilibrium dialysis method. In brief, the flour from all the samples were subjected to simulated gastro-intestinaldigestion by adjusting the pH to 1.35, followed by addition of pepsin (25 mL of pepsin in 0.1 mol/L HCl) and incubation in a shaker water bath at 37 °C for 90min. At the end of the incubation contents of the flask were centrifuged at 300 rpm. For 45 minutes and the supernant filtered through Whatman No. 44 filter paper ionisable iron was determined in a aliquots of the filterate at pH 1.35. In another aliquot pH was adjusted to 7.5 with NaOH and incubated at 37°C for 90 minutes in a metabolic shaker water bath. At the end of the incubation period the contents of the flask were centrifuged at 3000 rpm, for 45 minutes. The supernatant was and the filtered used for the determination of ionisable iron.

Nonheme iron is usually much less well absorbed than heme iron. All nonheme food iron that enters the common iron pool in the digestive tract is absorbed to the same extent, which depends on the balance between the absorption inhibitors and enhancers and the iron status of the individual. It is important, however, to note that not all fortification iron enters the common pool.

Iron availability from finger millet preparations:

The total iron, bio available iron and per cent availability of iron from finger millet dosa, idli, *Roti* and meal are given in Table 1.

Finger millet idli had 4.57mg and meal had 4.58mg% total iron without any significant difference between the two products. Finger millet dosa had a total iron of 5.04mg and *Roti* had 5.55mg both of which differed significantly compared to each other and with other preparations ($p<0.05$).

Though the total iron was good in all the 4

Table 1 : Total iron content, available iron and per cent available iron from millet recipes

Sr. No	Millet / Grain	Dosa			Idly			*Roti*			Meal		
		Total iron (mg)	Availa-ble iron (mg)	Availa-ble iron (%)	Total iron (mg)	Availa-ble iron (mg)	Availa-ble iron (%)	Total iron (mg	Availa-ble iron (mg)	Availa-ble iron (%)	Total iron (mg)	Availa-ble iron (mg)	Availa-ble iron (%)
1.	Control	7.93^{b}	2.03^{b}	25.6^{c}	1.88^{c}	0.125^{c}	6.59^{b}	4.8^{c}	0.25^{c}	5.2^{c}	3.87^{c}	0.32^{b}	8.2^{a}
2.	Finger millet	5.04^{c}	1.88^{c}	37.3^{b}	4.53^{b}	0.189^{b}	4.1^{c}	5.55^{a}	0.68^{b}	12.3^{b}	4.58^{b}	0.12^{c}	2.7^{c}
3.	Pearl millet	8.49^{a}	5.3^{a}	62.4^{a}	6.49^{a}	2.18^{a}	33.5^{a}	4.9^{b}	2.15^{a}	44.0^{a}	5.2^{a}	2.1^{a}	40.0^{a}
	F ratio	1529.88	4608.21	8769.62	1529.88	4608.21	8769.62	1529.88	4608.21	8769.62	1529.88	4608.21	8769.62

preparations, bioavailable iron content reduced drastically to 1.88mg in finger millet dosa, 0.68 mg in *Roti*, 0.189mg in idli and 0.128mg in finger millet meal with significant difference from each other. The *in vitro* iron availability of iron seems to be very low moist treated ragi compared to dry heat or roasted ragi preparations.

Per cent available iron was highest in finger millet dosa at 37.3% against 4.1% in idli, 12.3% in *Roti* and 2.7% in meal with significant difference between each other ($p<0.05$).

Total iron was significantly high in finger millet *Roti* ($p<0.05$) compared to other products, similarly finger millet dosa also differed significantly ($p<0.05$) but no significant difference was observed between iron content of idli and meal.

Iron extractability in finger millet doubled after 48h of fermentation at 30°C (Anthony and Chandra, 1998). During the same period, Ca and Zn extractability increased by 20 and 30.5%, respectively.

Pynaert *et al*. (2006) compared processed vs. unprocessed complementary foods (CF) in Tanzaina. The processed CF consisted of germinated, autoclaved and dried finger millet, kidney beans, roasted peanuts and mango puree. The same ingredient in identical proportions were used for the unprocessed CF. Iron solubility was higher in the processed samples (19%) than in the unprocessed samples (5%) ($p <0.05$).

Foods contain a large number of ligands for metal ions such as proteins, peptides, amino acids, carbohydrates, lipids and inorganic ions. Some of these ligands form insoluble complexes with the metal ions reducing the availability to absorption. However, some of those complexes make minerals more absorbable and, therefore, increase their bioavailability. Finger millet has high proportion of dietary fibre than many other millets. Health benefits associated with finger millet were delayed nutrient absorption due to high. Red colored varieties having pigmented test a were known to contain much tannin content and these are located in the said tissue of the grain. High content of tannins may reduce the iron availability.

Iron availability from pearl millet preparations :

The total iron was good in all preparations. Pearl millet *Roti* had 4.9mg of iron, which was least, followed by 5.2mg in meal, 6.49 mg of iron in idli and 8.49mg in dosa, in the increasing order of iron content and significant difference was found between the iron content of the four pearl millet preparations ($p<0.05$).

Bioavailable iron content has reduced to 2.15mg in *Roti*, 2.1mg of iron in meal, 2.18mg in idly and 5.3mg in dosa with significant difference between the preparations ($p<0.05$) indicating that bioavailability of iron was influenced by methods of preparation. The *in vitro* availability of iron was high in dosa, probably due to fermentation and shallow fry on iron tawa, seems to low steamed cooking method of pearl millet idly compared to dry heat or roasted pearl millet preparations.

Per cent available iron was highest in pearl millet dosa at 62.4% against in 33.5% in idly, 44.0% in *Roti* and 44.0% in meal. Significant difference was observed per cent availability of iron from the four pearl millet preparations ($p<0.05$) indicating effect of processing on per cent available iron.

Pearl millet had highest iron content in its whole grain form and was the major contributory factor iron in pearl millet recipes. The highest total iron, highest bioavailable iron including percent available iron from pearl millet dosa compared to other recipes($p<0.05$) could be attributed to the soaking, grinding and fermentation processes which might have improved bioactive protein and reduced the inhibitory factors like phytates and tannins, thereby increasing more iron accessible. Iron dosa pan must have also added iron to the total iron content of pearl millet dosa. Next to pearl millet dosa, pearl millet idli was significantly the next best product for total iron as well as bioavailable iron compared ($p<0.05$) to other products. But in idli per cent availability of iron was significantly lower than pearl millet dosa, *Roti* and meal, though the factors like soaking, grinding and fermentation were, similar to dosa processing which might have inhibited phytates and tannins the heat exposure in idli was limited because the product was steam cooked. Cause iron binding and absorption and steaming.

Iron content in pearl millet dosa had highest iron content due to lower phytic acid content then iron availability was increased in dosa and *Roti* on roasting and heating process. In dosa making ground batter was used, hence iron availability has increased.In moist heat method of preparations, as in meal preparations whole grain was soaked for few minutes, which might have decreased phytate content and thus per cent available iron increased. Baking on iron pan, was another factor to increase iron availability from *Roti*. From the above results it is imperative that soaking of grain components under chosen conditions could decrease the inhibitory

factors, especially phytic acid, considerably either due to leaching or due to partial hydrolysis.

The whole flour of grain has contained high amount of phytic, after milling or remove bran phytates content reduced then in flours or semi flour have less amount phytates due to this iron availability increased in processed foods.

Suma *et al*. (2014) reported that milling fractions like semi refined flour and bran rich fraction had significantly (P≤0.05) lower total iron content. Iron bio accessibility of the whole flour for Kalukombu and MRB was 3% and 7% respectively after gastro-intestinal digestion stimulation. The bio accessibility of iron was significantly (P≤0.05) higher from semi refined flour followed by whole flour and least from bran rich fraction.

Extrusion of weaning foods of pearl millet increases the protein digestibility whereas germination and probiotic fermentation causes significant improvement in protein profile and *in-vitro* mineral availability (Arora *et al*., 2011).

Iron availability from control/rice or wheat preparations :

The total iron, available iron and per cent availability of iron of rice preparations like dosa, idli and meal and wheat preparation *Roti* are given in Table 2. Total iron content was 7.9mg in rice dosa, which was highest, followed by 4.8mg in *Roti*, 3.8mg in meal and 1.8mg in idli, with significant difference between preparations (p<0.05) bioavailable iron was 2.037mg in dosa, 0.32mg in meal, 0.250mg in *Roti* and 0.124mg in idli with significant difference (p<0.01) between each other.

Per cent available iron was least in *Roti* at 5.2% against meal at 8.2%, idli at 6.59% and dosa at 25.6% with significant difference between each other. Hemalatha *et al.*, 2006 reported 23.05 % availability of iron from rice and black gram combination idli. Though rice based dosa had near values with 30% of available iron.

Phytic acid is found in high concentrations in cereals, reaching 3 to 6% of the weight of the grain (Febles *et*

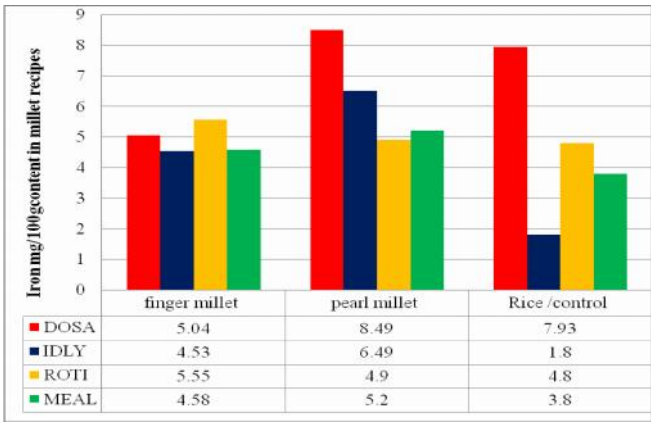

Fig. 1: Iron content of millet and rice recipes

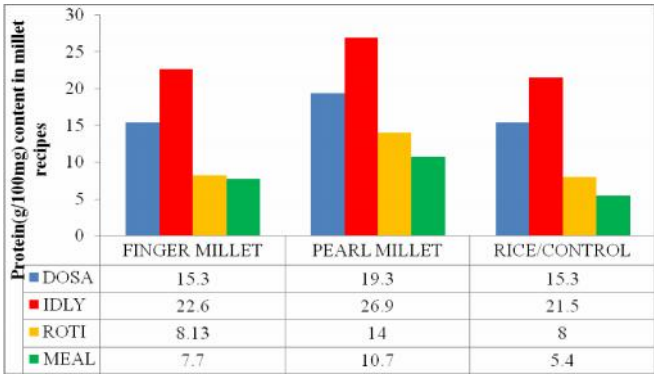

Fig. 2: Protein content of millet and rice recipes

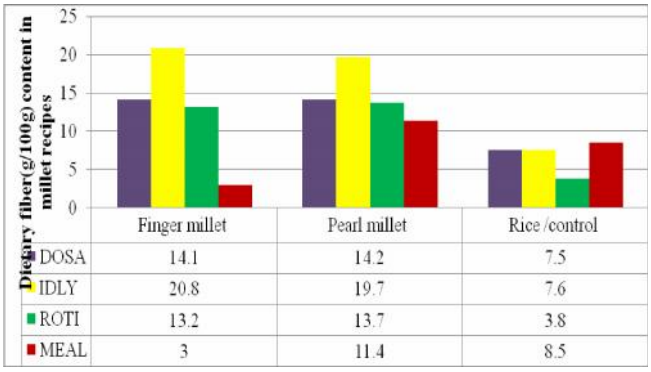

Fig. 3: Dietary fibre content of millet and rice recipe

Table 2: Effect of processing/ cooking on total iron, bioavailable iron and per cent available iron from millets

	Control			Finger millet			Pearl millet		
	Total iron	Avail. iron	% iron	Total iron	Avail. iron	% iron	Total iron	Avail. iron	% iron
Dosa	7.93^{a}	2.03^{a}	25.6^{a}	5.04^{b}	1.88^{a}	37.3^{a}	8.49^{a}	5.3^{a}	62.4^{a}
Idly	1.88^{d}	0.12^{d}	6.59^{c}	4.57^{c}	0.18^{b}	4.1^{c}	6.49^{b}	2.18^{b}	33.5^{d}
Roti	4.8^{b}	0.25^{c}	5.2^{d}	5.55^{a}	0.68^{c}	12.3^{b}	4.9^{d}	2.15^{c}	44.06^{b}
Meal	3.88^{c}	0.32^{b}	8.2^{b}	4.58^{c}	0.12^{d}	2.7^{d}	5.2^{c}	2.1^{d}	44.0^{c}
F ratio	1529.88	4608.21	8769.62	1529.88	4608.21	8769.62	1529.88	4608.21	8769.62

al., 2002). Reduction or degradation of phytic acid has been suggested for increasing the bioavailability of minerals.

Iron bio availability is low due to high levels of dietary phytates and fibres in millets. Processing techniques such as soaking, germination, fermentation and further cooking have been found to reduce significantly the levels of phytates and tannins by exogenous and endogenous enzymes formed during processing. Heat processing as in dosa frying, *Roti* roasting and boiling for meal preparation softens the food matrix, releases bound iron from protein and facilitates and availability.

The digestibility and hence, absorption of micronutrients such as iron is improved upon heat processing, which results in softening of the food matrix, and release of protein –bound iron, thus, facilitating its absorption (Lombardi-Boccia *et al*.,1995).

Conclusion:

Millet recipes like dosa, idly, *Roti* and meals were made with millets in pearl millet recipes were dosa and idly have high per cent of available iron compared with with rice and finger millet recipes. On fermentation available iron was increased and baking and boling method didnt improve the iron available in *Roties* and meals, compared between four recipes, dosa and idly have high available iron. In other aspect protein had negatively effect on iron available in dosa and dietary fibre had negative effect on other recipes.

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