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Bio-accessibility of iron from tamarind leaves-based recipes

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Abstract
The present investigation was planned with the objective to analyze the bioaccessibility of iron from tamarind leaves-based recipes. Recipes are tender/mature tamarind leaves chutney, dal and rice were prepared. Bioaccessibility of iron was estimated using invitro method simulating gastrointestinal digestion. Iron content in tender and mature tamarind leaves were 0.61 mg and 0.82 mg per 100 g, of which 0.04 mg (6.93%) and 0.03 mg (4.00%) respectively was bioaccessible. Iron content in tender and mature tamarind leaves chutney were 3.47 mg and 3.53 mg per 100 g, of which 0.03 mg (0.96%) and 0.20 mg (5.86%) respectively was bioaccessible. Iron content in tender and mature tamarind leaves dal were 2.33 mg and 2.36 mg per 100 g, of which 0.07 mg (3.16%) and 0.08 mg (3.40%) respectively was bioaccessible. From the results, iron bioaccessibility from tamarind leaves and recipes prepared from tamarind leaves were low compared to other green leafy vegetables.

Keywords: Tender and mature tamarind leaves. bioaccessibility of iron. dialyzable iron, total iron

Introduction
Tamarind (*Tamarindus indica* L.) is a dicotyledonous tree belongs to Caesalpiniaceae family. It is the third largest family of flowering plants with a total of 727 genera and 19,327 species. Tamarind is an economically important and most useful tree which grows wild in central and southern parts of India (Lewis *et al*., 2005) [13].

The leaves are consumed as green leafy vegetable. It contains high level of protein with many essential amino acids which help to build strong and efficient muscles. It is also high in carbohydrate, which provides energy, rich in the minerals, potassium, phosphorus, calcium, and magnesium. Tamarind leaves also provide smaller amounts of iron and vitamin A. It is an important leafy vegetable and food resource for the Thai population, the flower and leaf are eaten as vegetables (Prakash and Misra, 1988) [18].

In India, the leaves are made into a dish which is known as "Chindar". Tamarind tender leaves are also used as seasoning vegetable in some Thai food recipes because of their specific aroma and sourness (Coronel, 1991) [5].

Tamarind leaves are used to make curries, soups, salads, and stews in many countries, especially in times of scarcity (El-Siddig *et al*., 2006) [6]. The tender leaves of tamarind are also used in the preparation of various vegetarian and nonvegetarian (meat) foods.

Leaves ground into a paste with lime juice and heartwood of Acacia tundra wild are used in the treatment of boils to prevent suppuration and inflammatory swellings. The leaves are also used in the treatment of ulcers and the juice of the leaves is applied externally to treat rheumatism and external swelling in the Philippines and West Africa (Jayaveera, 1981; Rama Rao, 1975) [12, 19]. It has been reported by Pino *et al.*, (2002) [17] that the tender tamarind leaves are also used to produce an essential oil, which is primarily limonene and benzyl benzoate. The fruits of this plant showed anti-inflammatory, anti-bacterial and anti-diabetogenic effects (Maiti *et al.*, 2004) [15].

Tamarind leaves have several health benefits like antioxidant and anti-bacterial which will be helpful in curing liver diseases (Escalona-Arranz *et al*., 2010) [7]. The tamarind leaves and barks are used for the treatment of wounds, especially in central West Africa. While the bark is used in the treatment of diarrhoea in West Africa, the leaves are also used for the same purpose in East Africa (Reinout *et al.*, 2010) [21].

Hence the present study was planned with the objective to analyze the iron content of tamarind leaves-based recipes and to determine the bio accessibility of iron from tamarind leaves and tamarind leaves-based recipes.

Materials and Methods

The experiment was conducted during the year 2020-2021 at the Department of Food Science and Nutrition, College of Community Science, University of Agricultural Sciences, Dharwad. Mature tamarind leaves and tender tamarind leaves were collected from a fully-grown tree in Hi-tech Horticulture unit, University of Agricultural Sciences, Dharwad. The samples were collected, cleaned, dried and stored in an airtight container for further analysis.

The recipes were prepared in the laboratory, homogenized using pestle and mortar, and dried in hot air oven at 45 ± 20C until moisture free, packed in polyethylene pouches and stored under refrigerated conditions till further analysis. Recipes are tender/mature tamarind leaves chutney, dal and rice. Care was envisaged to prevent mineral contamination at every stage. Total iron in sample were estimated by injecting mineral solution into Atomic Absorption Spectrophotometer (Anon., 1965) [1]. Bioaccessibility of iron was estimated by *in vitro* method described by Luten *et al*., (1996) [14], involving simulated gastrointestinal digestion with suitable modifications. Bioaccessible iron in dialysed solutions were estimated by injecting the solution into Atomic Absorption Spectrophotometer.

Paired t-test were employed to test the significance of obtained results.

Recipes from tender tamarind leaves incorporation
Recipes from mature tamarind leaves incorporation

Fig 1: Incorporation of tender and mature tamarind leaves in traditional recipes

Results and Discussion

Bioavailability is the portion of a nutrient in food, which is absorbed and utilized. Utilization is the process of transport, cellular assimilation and conversion to a biologically active form (O'Dell, 1984) [16].

Table 1 indicates iron content and iron bioaccessibility from tamarind leaves. There was significant variation in iron content, bioaccessible iron and bioaccessibility between tender and mature tamarind leaves ($p \leq 0.05$). Iron content ranged from 0.61 to 0.82 mg per 100 g. Mature tamarind leaves had highest iron content than the tender tamarind leaves. Tender tamarind leaves had highest amount of bioaccessible iron (0.04 mg/100 g), compared to mature tamarind leaves (0.03 mg/100 g). Tender tamarind leaves showed highest iron bioaccessibility (6.93%) followed by mature tamarind leaves (4.00%). Ramiro *et al*. (2019) [20] reported that the cabbage had the highest proportion of bioaccessible iron (16.2%), followed by pepper (12.2%), kale (11.8%) and broccoli (9.7%) while spinach had the lowest (6.6%) proportion. Results of iron bioaccessibility in tamarind leaves in the present study are in the range of those mentioned from different authors. The variation in the bioaccessibility of this mineral is because of the tamarind leaves compositions including antinutrients.

Table 2 indicates iron content and iron bioaccessibility from tamarind leaves chutney. There was significant variation in bioaccessible iron between tender and mature tamarind leaves chutney ($p \leq 0.05$). Bioaccessible iron from tender tamarind leaves chutney was 0.03 mg per 100 g which was 0.96 percent of total iron content. Mature tamarind leaves chutney recorded the highest bioaccessible iron (0.20 mg/100 g) with a bioaccessibility percent 5.86. There was no significant difference ($p \leq 0.05$) in iron content between tender and mature tamarind leaves chutney. i.e., 3.47 to 3.53 mg per 100 g.

Table 3 indicates iron content and iron bioaccessibility from tamarind leaves dal. There was significant variation in bioaccessible iron and bioaccessibility percent between tender and mature tamarind leaves dal ($p \leq 0.05$). Mature tamarind leaves dal recorded the highest bioaccessible iron 0.08 mg per 100 g, which was 3.40 percent of total iron content 2.36 mg per 100 g. The bioaccessible iron from tender leaves dal was 0.07 mg per 100 g which was 3.16 percent of total iron content (2.33 mg/100 g). There was no significant difference ($p \leq 0.05$) in iron content between tender and mature tamarind leaves dal. i.e., 2.33 and 2.36 mg per 100 g respectively.

Table 4 indicates iron content and iron bioaccessibility from tamarind leaves rice. There was no significant difference in iron content and bioaccessible iron between tender and mature tamarind leaves rice ($p \leq 0.05$). Tender tamarind leaves rice contains 2.36 mg per 100 g iron had 0.05 mg per 100 g bioaccessible iron which was 2.45 percent of total iron content. Mature tamarind leaves rice had 2.44 mg per 100 g iron, bioaccessible iron was 0.04 mg per 100 g with 2.30 percent bioaccessibility of total iron content.

Table 1: Iron content and Iron bioaccessibility from tamarind leaves

Parameters	Tender leaves	Mature leaves	t value
Iron (mg/100 g)	0.61±0.01	0.82±0.02	62.00*
Bioaccessible iron (mg/100 g)	0.04±0.001	0.03±0.001	17.32*
Bioaccessibility (%)	6.93±0.35	4.00±0.21	23.73*

All values are expressed as mean ± SD of 3 replications on dry wt basis.
*-Significant at $p \leq 0.05$

Table 2: Iron content and Iron bioaccessibility from tender and mature tamarind leaves incorporated chutney

Parameters	Tamarind leaves incorporated chutney		t value
	Tender	Mature	
Iron (mg/100 g)	3.47±0.02	3.53±0.04	NS
Bioaccessible iron (mg/100 g)	0.03±0.001	0.20±0.008	45.17*
Bioaccessibility (%)	0.96±0.04	5.86±0.29	34.66*

All values are expressed as mean ± SD of 3 replications on dry wt basis.
*-Significant at $p \leq 0.05$, NS-not significant.

Table 3: Iron content and Iron bioaccessibility from tender and mature tamarind leaves incorporated dal

Parameters	Tamarind leaves incorporated dal		t value
	Tender	Mature	
Iron (mg/100 g)	2.33±0.01	2.36±0.02	NS
Bioaccessible iron (mg/100 g)	0.07±0.001	0.08±0.00	10.00*
Bioaccessibility (%)	3.16±0.06	3.40±0.02	11.13*

All values are expressed as mean ± SD of 3 replications on dry wt basis.
*-Significant at $p \leq 0.05$, NS-not significant.

Table 4: Iron content and Iron bioaccessibility from tender and mature tamarind leaves incorporated rice

Parameters	Tamarind leaves incorporated rice		t value
	Tender	Mature	
Iron (mg/100 g)	2.36±0.02	2.44±0.03	NS
Bioaccessible iron (mg/100 g)	0.05±0.001	0.04±0.006	NS
Bioaccessibility (%)	2.45±0.05	2.03±0.30	NS

All values are expressed as mean ± SD of 3 replications on dry wt basis.
*-Significant at $p \leq 0.05$, NS-not significant.

Bioaccessibility is the key to nutrient effectiveness which is defined as the proportion of nutrient in food that can be absorbed and utilized (Ballot *et al.*, 1987 and Gillooly *et al.*, 1983) [2, 8]. One of the determinants of iron absorption is the form in which it is present in food i.e., heme or non-heme iron. The absorption of non-heme iron is governed by the meal components and other factors operating in stomach and small intestine (Benito and Miller, 1988) [3].

In the present study, bioaccessibility of iron differed significantly among chutney (Table 2). Even though the low iron content was registered in matured tamarind leaves chutney, the availability was higher (5.86%), while tender tamarind leaves chutney recorded the least percent bioaccessible iron. Chawla *et al.* (1988) [4] reported that *in vitro* availability of iron from different green leafy vegetables was neither a function of their total iron content nor ascorbic acid but was slightly affected by oxalic acid content. Contrarily, the oxalic acid content of mature tamarind leaves chutney was higher (460.53 mg/100 g) compared to tender tamarind leaves chutney (400.40 mg/100 g) although other inhibitors were higher in mature leaves, vitamin C which is a known promoter of iron absorption was higher in mature leaves which could explain higher iron bioaccessibility. Comparatively, lower calcium was registered in spinach and shepu leaves (Gopalan *et al*., 2004) [9]. High levels of calcium also inhibit heme and non-heme iron absorption. The effect of calcium is independent of phosphate, the magnitude varying with the source and level of calcium intake, as well as iron status of the subject. Hallberg and associates reported that the mechanism for this interaction is unclear but may involve intracellular inhibition of iron transport (Hallberg *et al.*, 1992) [10].

Further, the variation in pulse i.e., red gram and black gram in tender and mature tamarind leaves dal (Table 3), nature of the pulse and physiological variation in the leaves might have altered the bioaccessibility.

Among both the tender and mature tamarind leaves rice, total iron content was lower in both tender and mature tamarind leaves rice (Table 4). While plain pressure-cooked rice had bioaccessible iron of 12.00 percent (Hemalatha *et al.*, 2007b) [11], the same decreased with the incorporation of green leafy vegetables and oil for seasoning (Hemalatha *et al.*, 2007b) [11].

Conclusion

Iron content in tender and mature tamarind leaves were 0.61 mg and 0.82 mg per 100 g, of which 0.04 mg (6.93%) and 0.03 mg (4.00%) respectively was bioaccessible. Iron content in tender and mature tamarind leaves chutney were 3.47 mg and 3.53 mg per 100 g, of which 0.03 mg (0.96%) and 0.20 mg (5.86%) respectively was bioaccessible. Iron content in tender and mature tamarind leaves dal were 2.33 mg and 2.36 mg per 100 g, of which 0.07 mg (3.16%) and 0.08 mg (3.40%) respectively was bioaccessible.

On the whole iron bioaccessibility from tamarind leaves and recipes prepared from tamarind leaves were low compared to other green leafy vegetables.

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