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STUDIES ON THE RETENTION OF IRON, ZINC, PHYTATE AND POLYPHENOLS CONTENT IN DIFFERENT RAW VARIETIES AND COOKED RECIPES OF PEARL MILLET *(Pennisetum typhoides)* IN NAGAUR, A DESERT DISTRICT OF RAJASTHAN

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ABSTRACT

The study was to assess retention of iron, zinc, phytate, and polyphenol contents in different raw varieties and cooked recipes of Pearl Millet. It was a cross sectional study. Studied 30 villages of ten tehsils/blocks of Nagaur district. Collected information from women of child bearing age. 30 Focus Group Discussions were recorded in which 291 males and 265 women key informants participated. A total of 5 raw varieties of Pearl Millet commonly consumed in Nagaur district i.e. 'Desi bajra', 'Pro Agro hybrid', 'MH-169', '118+154 Ghua Seed' and Pioneer' were collected from 10% of the women in LDPE pouches. Five samples each of Raw varieties and five standardized Cooked recipes (Sogra, Rab1 (PM Grains), Rab2 (PM Flour), Kadhi and Khitchri along with mixed flour of Raw varieties of Pearl Millet were tested for Iron, Zinc, Phytate and Polyphenols. Observed maximum Iron in 'Mixed Flour (5.99mg/100g) and MH-169' variety, followed by 'Desi bajra' (4.89mg/100g). Maximum Zinc was observed in 'Mixed Flour' i.e. 3.64mg/100g, followed by Desi bajra (3.39mg/100g). Phytate was maximum in 'Desi bajra' (468.2mg/100g). In Cooked recipes, retention of Zinc and Iron increased in rab1 (PM Grains) preparation i.e. 3.64 to 4.40 mg/100g and 5.99 to 10.5mg/100g respectively and Phytates were reduced. Combination of Rab1(PM Grains), Khitchri and Kadhi are good, where processes of Soaking, Pounding and Dehusking were involved due to which Iron retention increased and Phytates reduced. The appropriate preparations of Pearl Millet have to be promoted to enhance quantity of micronutrients especially, Iron and Zinc.

Keywords: Iron, Zinc, Retention, Raw, Cooked, Pearl Millet

INTRODUCTION

Thar Desert in Rajasthan state is represented by 12 desert districts i.e. Ganganagar, Hanumangarh, Bikaner, Churu, Jhunjhunun Sikar, Nagaur, Pali, Jodhpur, Jalor, Barmer, and Jaisalmer. Nagaur district with its central location, shares its border with several other districts of Rajasthan(Census.1994). Nagaur, in terms of climate, is conspicuous for extreme dryness, large variations of temperature and highly variable rainfall. Pearl Millet (*Pennisetum typhoides*) commanly known as 'Bajra' belongs to the "warming" foodstuffs and is the staple diet of desert region. The proportion of Pearl Millet production was highest i.e. 39.8 percent followed by wheat (14.1%), Green gram (10.6%), Mustard (7.7%), Til (6.5%) and Moth (6.1%) in 2008 in Nagaur district. The total population of Nagaur district is 27,75,058 (Rural-22,97,721 & Urban-4,77,337) residing in 4,21,118 households in 1570 villages and 247 wards according to National Census of 2001. Among the major Pearl Millet producing regions, per capita consumption was highest (92 kg $year^{-1}$) by the rural population in the western region of Rajasthan (WRR), followed by the dry areas of Gujarat (DAG)(Rao et al 2006) .

Micronutrient malnutrition is one of the burning problems in developing countries. Multi-centric studies carried out by ICMR[4], NNMB[5]and NFHS[6]-3, (Singh et al 2006) show that the prevalence of anemia, vitamin A deficiency and iodine deficiency disorders continues to be high, though there is a small decline in IDD in India. In study(Singh Madhu 2006) of Jodhpur district, Pregnant & lactating women suffered higher from anemia (81%) in comparison to other studies i.e. NIN[8] (MND) 2003 (76.5%) and NFHS[6] III (2005) (61.2% in Rajasthan & 57.9% in India) and 52.0% in Non industrialized countries and 22.7% in industrialized countries according to (WHO, 2001). In Iron deficiency anemia, it is now recognized that even without anemia, mild to moderate iron deficiency occurs and has adverse functional consequences. It adversely affects the cognitive performance, behavior and physical growth of infants & preschool children, immune status and morbidity from infections and reduces work performance(WHO; 1992, WHO; 1996, WHO; 1992). Zinc is an essential micronutrient for healthy functioning of the human body. Though present in tiny amounts, it is critical to life and its deficiency can have a variety of adverse consequences. Zinc deficiency may occur due to

diets inadequate in bio-available Zinc, certain diseases like diarrhea, loss of Zinc in processed foods, and soil deprived of Zinc, which can reduce the Zinc content in agricultural products. To combat with the micronutrient deficiencies, food based approaches has to be promoted. In the desert(Archana 1998) areas, staple diet is Pearl Millet which is also an important dietary source of Iron and Zinc for the at risk populations in Indian states and districts where Pearl Millet is a primary staple food crop. Pearl Millet is a significant source of dietary energy and nutritional security for poor farmers and consumers in desert areas of Rajasthan in India. As per the nutritive value of Indian foods (ICMR, 1989), Pearl Millet contains more Iron (8.0 mg) and Zinc (3.1 mg) as compared to Wheat (Iron- 4.9 mg, Zinc 2.2 mg) and Rice (Iron- 2.8 mg & Zinc- 1.4 mg) per 100 gm of edible portion. Some studies(Huang et al 1982, Asp NG,1996) in literature revealed that processes of preparation of Pearl Millet recipes such as blanching and fermentation resulted in the reduction of Polyphenols and Phytic acid content of Pearl Millet flour which are the inhibitors of Iron absorption. Pearl Millet has been recommended for several therapeutic purposes, as it has been found to inhibit tumor development(ICMR, 1989) and cholesterol levels(Singh Madhu et al 2006). Nutrition background studies were essentially required in desert area which is the Pearl Millet belt in India and population habitually consumes large quantity of Pearl Millet due to demographic and economic reasons.

In view of the fact that Pearl Millet is a major source of micronutrients and is grown and consumed extensively in rain-deficient areas, the potential to promote consumption of micronutrients through bio-fortified Millet is attractive as a sustainable food-based approach to enhance Iron nutritional status. For achieving this baseline nutritional studies were required to know their dietary pattern, their method of cooking and processing so as to know the adequacy of Iron, and Zinc etc in the diet of the local residents. This study aimed to study the retention of Iron, Zinc, Phytate and Polyphenols content in different raw varieties and Cooked recipes of Pearl Millet *(Pennisetum typhoides)* in Nagaur, a desert district of Rajasthan.

This work is a part of large project on "Back ground studies on Pearl Millet in Jodhpur, Rajasthan" funded by CIAT/IFPRI/Harvest Plus, USA report(. Singh Madhu et al 2011).

MATERIAL AND METHODS

The study was done in two parts i.e. collection of data from the eligible women of child bearing age (15-45 years) and a child between 6-59 months of age from the selected household and the biochemical analysis of the collected samples from the field. The sampling has been described in detail for whole study.

STUDY AREA

A cross sectional study was carried out in all ten tehsils / blocks in Nagaur, a desert district of Rajasthan in India as per Govt. of India census 2001.

STUDY DESIGN

30 cluster sampling approach (as propagated by WHO) was adopted in dietary survey keeping in view the operational feasibility. The Sampling unit was kept at household level as in each house, mother and child were available. The Sample size was calculated on the basis of prevalence of Iron deficiency in diet of women in desert area as reported in scientific literature (Singh et al 2009) as 20%, level of confidence of 95% relative precision of 20% and design effect of 2 Using formula $(Z\alpha)^2$ $Q/(L^2)$ P, sample size worked out to be 768, adjusted for a 20 percent non response. The sample size was rounded of to 900 from Nagaur district of Rajasthan or 900 / 30=30 households per cluster. In Nagaur, geographically, a cluster consisted of a village. These 30 clusters / villages were selected from 10 tehsils (Sub-districts) of Nagaur district by means of simple random sampling using the Indian census[2]. In each cluster / village, 30 household were selected on the basis of simple random sampling technique using a complete list of all households in each village.

INCLUSION CRITERIA

Only those households were selected which had women of child bearing age (15-45 years) and children of age between 6 to 59 months.

EXCLUSION CRITERIA

If in one household, women of child bearing age had two or more children with age of 6 to 59 months, then only one child at that household was considered for the study. In selected villages a random walk method starting from a central place (usually a temple) in the village and proceeding in at least four different directions was adopted. A household was selected only if eligible women of child bearing age (15-45 years) and a child between 6-59 months of age were among the members of the family. A total of 900 households (HHs) were covered from 10 tehsils/ blocks of Nagaur District of Rajasthan covering 900 women of child bearing age i.e. 15-45 years age group and 900 children belonging to 6-59 months of age.

In this paper, biochemical part is being presented for which most of the popular varieties cultivated and consumed were considered for estimation of nutrient contents. Sub samples i.e. 10% of women of selected household were requested to provide raw varieties of Pearl Millet in LDPE pouches. These were brought to laboratory for estimation of Iron, Zinc, Phytate and Polyphenols retention in the laboratory. At each village level Focus Group Discussions were conducted for collection of information regarding seasonal pattern and time trends in Pearl Millet production and consumption, traditional processing and cooking methods etc. At each village level, focus group discussions were conducted from two types of key informant groups i.e. One group of 6 or more male persons (key informants) mainly key persons from village i.e. Panch, Sarpanch, teacher etc from the village to provide the above mentioned information. Second group consisted of 6 or more knowledgeable women (key informants) including Aganwari workers for providing the

information regarding the preparation of different type of recipes from Pearl Millet, their consumption and preservation etc. They also demonstrated the method of preparation of different recipes made up from the Pearl Millet which were commonly consumed by the villagers. The Team learnt and standardized five commonly consumed recipes of Pearl Millet in the field in Nagaur district of Rajasthan. A total of 30 Focus Group Discussions were recorded in which 291 male and 265 women key informants participated. A total of 5 Raw varieties of Pearl Millet commonly consumed in Nagaur district i.e**.** 'Desi bajra', 'Pro Agro hybrid', 'MH-169', '118+154 Ghua Seed' and Pioneer' were collected. The most common recipes prepared from Pearl Millet in the study villages were Sogra, Rab1 (Pearl Millet Grains), Rab2 (Pearl Millet Flour), Kadhi and Khitchri (Kheech) which were learnt by team in the field and standardized. Five samples each of Raw varieties and five Cooked recipes along with mixed flour of Raw varieties of Pearl Millet were tested for Iron, Zinc, Phytate, and Polyphenol retention.

The samples of Raw varieties of Pearl Millet collected from field were taken by the project staff to laboratory of Baroda Pearl Millet Center (Department of Foods and Nutrition, A WHO collaborating Center for Health Promotion, Faculty of Family and Community Sciences, MS University of Baroda, Vadodara, Gujrat) for analysis of Iron, Zinc, Phytate, and Polyphenol retention. Pearl Millet Project staff also prepared the five standardized recipes of Pearl Millet in the Baroda laboratory and dried them for testing to be done for above mentioned parameters. The estimation of Iron and Zinc in both Raw and Cooked recipes of Pearl Millet was done by Atomic Absorption Spectrophotometer, by Diacid mixture of HNO & HCLO in 3:1 ratio (Ryan et al, 2001) and Phytate from Raw Pearl Millet Samples using Official AOAC, Anion Exchange and Quantitative Determination of Total Phenol, method propagated by Lowry, et al. 1951. Statistical analysis was done using Stata10 software.

RESULTS

The results of biochemical analysis of Zinc, Total Iron, Phytates and Total Phenols in Raw and Cooked Pearl Millet Based Recipes have been shown in Table 1.

The results of the Total Zinc content of Raw and preparations of different varieties of Pearl Millet, revealed that the total zinc content in Raw varieties ranged from 2.34-3.64 mg/100g, highest in Mixed Flour and lowest in MH -169, with an average of 3.09 mg/100g, whereas in Cooked recipes ranged from 3.59-4.84mg/100g, highest in Rab2 (a preparation from Pearl Millet Flour as shown in Table 2), with an average of 4.09mg/100g.

TOTAL IRON CONTENT OF RAW PEARL MILLET

The results of the Total Iron content of Raw and preparations of different recipes of Pearl Millet, estimated using the atomic absorption spectrophotometer (AAS) revealed that the Total Iron content in Raw varieties ranged from 4.60-5.99mg/100g, highest in MH -169 variety and mixed flour and lowest in 118 + 154 Ghua variety, with an average of 5.24mg/100g (Table 1).

The Iron content estimated in cooked samples ranged from 5.29-10.5mg/100g and, highest in Rab1 (a preparation from Pearl Millet Grains) and lowest in Rab2 (a preparation from Pearl Millet Flour) and Khichadi, with an average of 7.49mg/100g (Table1). In case of Sogra, (Chapati made from Pearl Millet Flour), the retention of Iron was more when prepared on Iron Tawa (IT) (9.99mg/100g) in comparison to Mud Tawa (MT) (6.31mg/100g).

PHYTATE FROM RAW PEARL MILLET SAMPLES USING OFFICIAL AOAC, ANION EXCHANGE METHOD

The results of the Phytate content of Raw and Milled varieties of Pearl Millet (n=6), along with the Phytate content of Cooked Pearl Millet based traditional recipes on a dry weight basis estimated using spectrophotometer are presented in the tables 1. Table 1 revealed that the Phytate content in Raw varieties ranged between 300.8 to 537.0mg/100g with an average of 427.3mg/100g highest content was obtained in the sample of Pro Agro hybrid and lowest were observed in Mixed Flour.

PHYTATE CONTENT OF COOKED PEARL MILLET BASED RECIPES

Table 1 revealed that the Phytate content in Cooked samples ranged between 200.5- 267.4mg/100g with an average of 233.9mg/100g. The highest content was found in Rab2 (Pearl Millet Flour) and Kadhi followed up by Sogra, Khichadi & Rab 1 (Pearl Millet Grains).

In biochemical analysis, Phytate content shows that we have a really high Phy/Zn ratio, way above the 15 cut off value. This provides us with sufficient evidence to assume low bioavailability for both Iron and Zinc.

TOTAL PHENOL CONTENT OF RAW PEARL MILLET

The results of the Total Phenol content of Raw and Milled varieties of Pearl Millet (n=6), along with the Total Phenol content of Cooked Pearl Millet based traditional recipes on a dry weight basis estimated using spectrophotometer as shown in the tables 1 revealed that the Total Phenol content of Raw Pearl Millet ranged between 120-380 mg/100g with an average of 295mg/100g. The highest Total Phenol was observed in 118 + 154 Ghua seeds and lowest was observed in MH -169.

TOTAL PHENOL CONTENT OF COOKED PEARL MILLET BASED RECIPES

Analysis revealed that the Total Phenol in Cooked samples ranged from 220 to 320mg/100g with an average of 276 mg/100g the highest content being in Khichadi and lowest in Kadhi.

Table 1- Results of zinc, total iron, phytates and total phenols in raw and cooked pearl millet based recipes

S.No.	Food Sample	Zinc (mg/100g)	Iron (mg/100g)	Phytate (mg/100g)	Total phenol (mg/100g)
Raw varieties					
1	118+154 Ghua Seed	3.25	4.60	467.2	380
2	Desi bajra, District Nagaur	3.39	4.89	468.2	340
3	MH-169, District Nagaur	2.34	5.99	322.8	120
4	Pro Agro hybrid, District Nagaur	2.65	4.90	537.0	370
5	Pioneer	3.29	NA	468.0	350
6	Mixed Flour	3.64	5.99	300.0	210
	Mean	**3.09**	**5.24**	**427.3**	**295**
	Range	**2.34-3.64**	**4.60-5.99**	**300.8-537.0**	**120-380**
Cooked Recipes					
7	Rab1 (Pearl Millet grains)	4.40	10.5	200.5	270
8	Rab2 (Pearl Millet flour)	4.84	5.29	267.4	260
9	Khitchri (Kheech)	3.59	5.29	200.5	320
10	Sogra	3.89	9.99 (IT) 6.31 (MT)	234.0	310
11	Kadhi	3.74	6.39	267.2	220
	Mean	**4.09**	**7.49**	**233.9**	**276**
	Range	**3.59-4.84**	**5.29-10.5**	**200.5-267.4**	**220-320**

Table 2- Standardized procedure used for preparation of Pearl Millet Recipes in the present study

	Recipe	Ingredient	Procedure
1	**Sogra**	Pearl Millet Flour- 250g, Salt- 5g, Water- 150 ml	Knead the Pearl Millet Flour with above mentioned quantity with salt added into it. Prepare chapatti with hands instead of using dough kneading plate and rolling pins as it tastes best when prepared like this. The time taken for preparing Sogra is 5 to 10 minutes. Sogra is eaten with butter milk or vegetable usually consumed
2	**Rab1 (Pearl Millet Grains)**	Pearl Millet Grains- 80g, Butter Milk- 1 liter, Salt- 5g	Take the above mentioned quantity of Pearl Millet grains and soak it in small amount of water for 15 to 20 minutes. Pound the soaked Pearl Millet grains with mortar and pestle till granulated into small pieces. Then dehusked the granulated pearl millet grains with 'Chaj'(a kind of broad plate made up of bamboo sticks) or with simple plate. Pour it in butter milk slowly – slowly and continuous stir it with salt added. Boil it with continuous stirring. This process is going for 15 to 20 minutes. This preparation is eaten with Sogra and powered with hands.
3	**Rab2 (Pearl Millet Flour)**	Pearl Millet Flour- 50g, Butter Milk- 1 liter, Salt- 5g	Take the above mentioned quantity of Pearl Millet flour and pour it slowly and continuous stir it with salt added. Boil it with continuous stirring. This process is going on for 15 to 20 minutes. This preparation is eaten with Sogra and powdered with hands.
4	**Kadhi**	Pearl Millet Flour- 50g, Butter Milk- 1 liter, Salt- 5g, Turmeric Powder-1.25g, Red Chilli Powder- 5g, Coriander Powder- 5g, Til Oil (Gingerly Seeds Oil)- 30 ml, Cumin Seeds- 2.5g	First mix 50g of Pearl Millet flour in 1 liter butter milk properly. Then add mentioned amount of salt, turmeric powder, red chilli powder and coriander powder and mix it well. Take 30g Til oil in cooking pan and pour cumin seeds, after that seasoned with oil, pour prepared butter milk solution and keep on continuous stirring. Kadhi is prepared within 25 to 30 minutes. It is consumed with Sogra and Kheech etc.

5	**Khitchri (Kheech)**	Pearl Millet Grain- 250g, Salt- 5g, Moth Beans- 15g, Green Gram- 15g, Water- 1200 ml	Take the above mentioned quantity of Pearl Millet grains and soak it in small amount of water for 30 minutes. Pound the soaked Pearl Millet grains with mortar and pestle till granulated into small pieces. Then dehusked the granulated Pearl Millet grains with 'Chaj'(a kind of broad plate made up of bamboo sticks) or with simple plate. Take 1200 ml of water and boil it, take dehusked granulated Pearl Millet grains then pour it in boiling water with mentioned amount of moth beans and green gram. Boil it on slow gas. Stir it continuous still cooking. Ready to eat either with sugar, pure Ghee, curd and butter milk etc. The recipe is prepared within 30 to 40 minutes

DISCUSSION

Nutrition background studies are required in the desert area which is the Pearl Millet belt in India. In view of the fact that Pearl Millet is a major source of micronutrients and is grown and consumed extensively in rain-deficient areas, the potential to promote consumption of micronutrients through bio-fortified Millet is attractive as a sustainable food-based approach to enhance Iron nutritional status. Millet Network of India, 2010 also stressed to include Millets in the public food systems of India. Micronutrient-rich Millets are identified under the Harvest Plus program as the most promising food crop and several varieties may find beneficial application in the communities subsisting mainly on millets as staple food.

The study revealed that five varieties of Pearl Millet were consumed in Nagaur district i.e**.** 'Desi bajra', 'Pro Agro hybrid', 'MH-169 (commonly consumed) and '118+154 Ghua Seed', and Pioneer' (Rarely consumed). The most common recipes prepared from Pearl Millet in the study villages were Sogra, Rab1 (Pearl Millet Grains), Rab2 (Pearl Millet Flour), Kadhi and Khitchri (Kheech).

It was observed that maximum Iron was found in 'Mixed Flour (5.99mg/100g) and MH-169' variety, followed by 'Desi bajra' (4.89mg/100g). Maximum Zinc was observed in 'Mixed Flour' i.e. 3.64mg/100g, followed by Desi bajra (3.39mg/100g). Phytate was maximum in 'Desi bajra' (468.2mg/100g), whereas, Total Phenols in '118+154 Ghua seeds' (380mg/100g). Trends indicated that MH-169, Mixed Flour and Desi Bajara varieties of Pearl Millet were observed to be good as the contents of Total Phenols and Phytate were less and Iron was more in comparison to other varieties which need to be promoted in the desert area.

In the cooked Pearl Millet based recipes retention of Zinc and Iron increased in rab1 (Pearl Millet Grains) preparation i.e. 3.64 to 4.40 mg/100g and 5.99 to 10.5mg/100g respectively. Analysis revealed that retention of Phytate and Phenols were reduced after cooking in most of the preparations where processes of Soaking, Pounding and Dehusking were involved such as Rab1 (Pearl Millet Grains), Khitchri and Kadhi. Combination of Rab1 (Pearl Millet Grains), Khitchri and Kadhi are good, where processes of Soaking, Pounding and Dehusking were involved due to which Iron retention increased and Phytates and Polyphenols were reduced. Different processing method significantly reduced the Polyphenol content as reported in literature. In one of the study in Haryana (Archana 1998; Nazni and Shalini, 2010), it was seen that blanching of Pearl Millet grains resulted in significant reduction in Polyphenol (28%) and Phytic acids (38%). In another study(Kheterpaul et al,2006), natural fermentation at 20, 25, and 30^0 C for 72 hours brought about a significant reduction in Phytic acid content of Pearl Millet flour. As Polyphenol is present in the outer layer of the grain, while Pounding and Dehusking process for preparing above mentioned traditional recipes made up of Pearl Millet in the studied area, outer layer is removed leading to the reduction of Polyphenols which in turn helps in the increase of Iron and Zinc content in these recipes. (Chandrasekara and Shahidi 2011) reported that the phenolic extract of kodo millet exhibited higher inhibition activities against oxidation of LDL cholesterol and liposome than that of Pearl Millet. Other studies (Reddy et al 1982, Duodu et al 1999; Nazni and Pradheepa, 2010) in the literature reported that Polyphenol affect the bioavailabilty of the minerals. Pearl Millet has high content of Iron (8mg/100g) and Zinc along with high content of fiber which helps in the reduction of anemia, constipation and other non communicable diseases. Potential health benefits and its possible neutraceutical properties of Pearl Millet have been highlighted in the literature (Vanisha et al 2011).

In the desert areas, staple diet is Pearl Millet which is also an important dietary source of Iron and Zinc for the at risk populations in Indian states and districts where Pearl Millet is a primary staple food crop and Iron deficiency Anemia exists which is of public health significance. Pearl Millet is main staple diet (63.0%) of rural areas of Nagaur district, followed by wheat (26.7%), revealing that it is a significant source of dietary energy and nutritional security for rural populations (Singh Madhu et al 2011; Nazni and Shalini, 2010).

In biochemical analysis, Phytate content shows that we have a really high Phytate/Zn ratio, way above the 15 cut off value. This provides us with sufficient evidence to assume low bioavailability for both Iron and Zinc.

MH-169 variety of Pearl Millet was observed to be best as the contents of Total Phenols and Phytate were less and Iron was more in comparison to other varieties, followed by Mixed Flour and Desi Bajara. Among the cooked recipes, combination of Rab1(Pearl Millet Grains), Khitchri and Kadhi is best, where processes of Soaking, Pounding and Dehusking were involved due to which Iron retention was found good and Phytates reduced. In case of Sogra, (Chapati made from Pearl Millet Flour), retention of Iron was more when prepared on Iron Tawa (9.99mg/100g) in comparison to Mud Tawa

(6.31mg/100g). Micronutrient enriched millet varieties may find beneficial application in the communities those subsisting mainly on Pearl Millet as staple food in reducing the micronutrient deficiencies in this area. The study suggests further research in this direction.

The study indicated that attempts to develop/utilize the Pearl Millet varieties constituting high content of Iron and Zinc & low Phytate and Polyphenol may be made in view to reduce the micronutrient deficiencies in the desert population, as Pearl Millet is the main staple food for their subsistence. The appropriate combinations and the preparations of the food preparations of Pearl Millet where processes of Soaking, Pounding and Dehusking were involved, needs to be promoted to enhance the quantity of micronutrients especially Iron and Zinc. Multi-location Bio-Efficacy trials should be carried out in different states like Gujrat, Rajasthan and Maharashtra in India, where base line work has already been carried out. For dissemination of the results of the study, there is an urgent need to produce a range of educational materials highlighting the health, nutrition and therapeutic values of different Pearl Millet varieties & their products aimed at desert population/consumers (villagers) and ecological values of millets addressing the farmers. The study suggests further research to determine the Varietal difference versus processing products versus Nutrients in the desert area.

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