

# A Review On: Role of Pearl Millet Derived Gluten Free Product and its Benefit in Treating Iron Deficiency Anaemia in Celiac Patients

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## ABSTRACT:

**Hidden hunger** is a global issue and is coming up as a alarming problem for mankind. At the same time world's most popular countries data showed the occurrence of Celiac Disease, mostly popular in India, Brazil, Russia also in US. 5-8 million people of India is expected to have celiac disease which is not a number can be ignored. The Strict Gluten Free Diet (GFD) is the only therapy intended for celiac patients, as a result most of the patient suffers from Iron Deficiency Anaemia which is one of the most reported additional intestinal manifestations of celiac disease. Today's market lacks the proper gluten free diet products. Most of them are either too costly or not nutrient dense. Millets being a Nutri cereal and old-style staple food of the dry land areas of the world can work as wonder in treating this problem. Among millets, Pearl millet is famous and important grain in the dry and semitropical areas of many developing countries. Proper fortification, enrichment and introducing millets in the plate of celiac patients are showing beneficial result in improving their health status. Our present study will review the part of pearl millet derived product and their efficacy, in treating iron deficiency anaemia in celiac patients.

## INTRODUCTION:

Malnutrition is now developing as a global problem. With climate change and lower amount of food supplies with growing population is a matter of concern for mutually developed in addition evolving countries. Current information since food and agricultural organization reveals that the measure of malnourished individuals in world has amplified up to 821 million. **Hidden hunger** which is mainly micro nutrient deficiency is the most alarming malnutrition problem globally (Srivastava et al. 2021). Micronutrient are other nutrients important for human body for cellular growth and metabolism (Kennedy et al. 2003). According to the data of 2011, Global Hunger Index Report (IFPRI), India is under one of those country where hunger is alarming (Saxena & N. C. 2012)

Among many nutrient deficiency **iron deficiency anemia** is a widespread malnutrition problem as its lowers the overall productivity Chellan et al. (2010). Anemia is well-defined by reduction in the oxygen carrying volume in RBC, which is a outcome of either decrease in the quantity of hemoglobin or the total number of red blood cell present. (Kennedy et al. 2003)

There is various etiology for developing iron deficiency anemia in this study we will highlight iron deficiency anemia in celiac patients. Clinical experiences give data about how patients with celiac shows the clinical and subclinical signs of anemia and iron deficiency (Repo et al. 2017). Iron deficiency

anaemia is a mutual sign in celiac patients, which is present about approximately in 40% of them (Stefanelli et al. 2020)

Celiac disease, which is an autoimmune enteropathy which is triggered when patients consume anything having gluten protein. Gluten is most abundantly present in wheat, rye, barley as their major protein component. In 95% patients, the two genes namely histocompatibility leukocytes antigen (HLA)-DQ2 besides DQ8 genotypes are the chief stimulus (Catassi et al. 2008).

The digestion of gluten activates an autoimmune reply which in order destroys the villous building of the small intestine, which in a long run result in a flat mucosa. Different signs and symptoms are included namely weight loss or weight gain, steatorrhea, discomfort in abdomen, and anaemia due to small intestine can no longer absorb the necessary nutrients also there is a reduction in the enzymatic activity and as a result different deficiencies take place. CD is a result of mainly 3 important factors which gradually end up with flat mucosa they are- genetic susceptibility, environmental factors, and immunologically based inflammation (Arendt et al. 2008)

Even few decades ago celiac disease was a very uncommon disease while affecting mainly some children and the ancestors of European population. But over the past 2 decades it came up as a major public health concern. It is reported most of the patients belongs to other parts of world with major Caucasian populations such as North America, Australia, and Brazil. In past 2 decades according to population-based data about the prevalence of celiac disease says, it is now common in middle East, India and many other countries.



**Figure 1 Singh et al. 2018**

Fig-1 Worldwide celiac disease's seroprevalence rates for various countries data are represented Values were classified into 4 groups of percentiles representing the 0-25<sup>th</sup> percentile which is in light grey to 76<sup>th</sup> to 100<sup>th</sup> percentile that is in dark black

From world's most 10 popular countries, data showed the availability of CD patients mostly in India, Brazil, Russia, and US (Singh et al. 2018)

In India celiac first introduced in the year of 1960's. A study on the population of Northern India, gives a result of prevalence of cd 1.04% that is 1 in 96 and the prevalence of positive serology test anti -tTGab test is 1.44% that is 1 in 69 person. It is more common in the states of Delhi , Rajasthan, Punjab , Haryana because their diets are abundant in wheat products .Based upon another studies 5-8 million people of India is expected to have celiac disease which is not a small number (Makharia et al. 2011)

A **strict gluten free diet (GFD)** practice is the only remedy for celiac disease. If one can strictly maintain a gluten free diet, then their symptoms can resolve also clinical, histological and laboratory findings can get back to normal position. The nutritional deficiency that are found in patients that is due to GFD and CD itself. Nutrient deficiencies can even result in several neurological dysfunction if not treated.

Several studies shows the insufficiency of nutrients, in different GFD raw materials. Anemia, which is stated to occur in 5%–40% of patients in the West and in more than 80% of patients in developing countries, is one of the most reported extraintestinal manifestations of CD. The most common form of anemia that is present in CD is iron deficiency anemia (IDA) (**Di Nardo et al. 2019**). So, diet rich with nutrient dense food are a necessity.

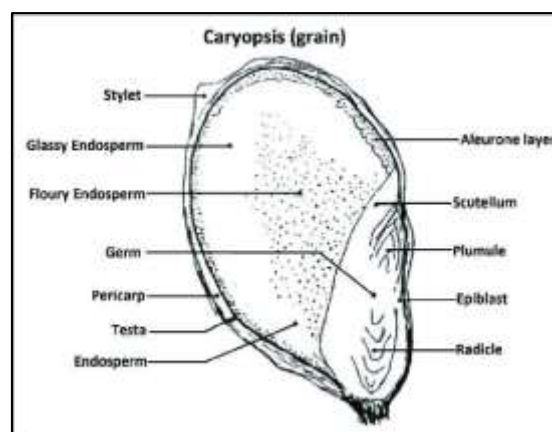
Although different oral supplements, products having ferrous sulphate (FS) as an iron replacement is also available, which are resulted in a poor tolerance among the CD patients

In review article it's been discussed, how iron-based products are well tolerated than FS, but their effectiveness is lesser in correcting IDA, in CD patients (**Verma & A. K. 2021**) although Indian market have not much gluten free product available.

GFD alone can prevent IDA, fortification and enrichment of GFD products will improve the diet in long term (**Kupper & C 2005**)

Not only that GFD also prevents the etiology of different autoimmune diseases namely hepatitis, inflammatory bowel disease and insulin dependent diabetes mellitus (**Hosseini et al. 2018**), at this point millets are great options for making gluten free products for CD patients, while improving their deficiencies with their effectiveness and Nutri cereal qualities.

Millets are the traditional staple food of the dry land regions of world. They are Nutri cereal with high nutrient content including, protein, essential fatty acids, minerals, different vitamins, and dietary fiber. Crop is favored because of its productivity and potential of growing in dry and high temperature



**Figure 2 General structure of millet grain Dayakar Rao et al. 2017**

In India , millets are grown on about 17 million ha also the annual production of them are 18 million tones and contribute to about 10 % to the country's food grain basket Among many millets pearl millet is famous and important grain in the arid and subtropical regions of many developing countries (**Dayakar Rao et al. 2017**)

India is the largest single producer of bajra, both in the terms of area and production .Its production area is about 9.3 million hectares and produce 8.3 million tons of crops (**Amarender Reddy et al. 2013**)



Figure 3 Area , production and productivity of pearl millet since 2000 **Satyavathi et al. 2021**

Researchers proving how bajra is having better nutritional quality than many crops with carbohydrate(67.5gm/100g) High protein (6-21%), energy (361kcl/100g), minerals like iron, zinc different vitamins, less glycemic index and dietary fiber (20.4%) content. Various processing techniques namely soaking germination, decortication or dehulling, popping, fermentation are applied for better bioavailability by removing the antinutrients like polyphenols, phytates. These processes helping in further commercialization, and better adopting capacity among general population.

For this reason, pearl millet is having potential to combat iron deficiency anaemia in celiac disease, as it increases the blood hemoglobin level and also it is anti-allergic and gluten free. **(Rathore et al. 2016)**

With versatile amazing nutritional quality pearl millets can help in eliminating micronutrient deficiencies in developing countries and its gluten free property makes it ideal for people with gluten allergy **Satyavathi et al. 2021**

**In this recent study we would establish the effectiveness of pearl millet in treating IDA in celiac patients**

**AIMS AND OBJECTIVES**

**AIM:-**

- To analyze the role of gluten free product derivatives of pearl millet
- To find out the benefit in treating iron deficiency anaemia in celiac patients.

**OBJECTIVES**

- To know about, the detailed nutritive value of pearl millet and the different available products.
- To study about celiac patient and their proneness towards iron deficiency anaemia .
- to understand the effectiveness of pearl millet and its products in curing CD.

**REVIEW OF LITERATURE : (millet in celiac disease and anaemia)**

SERIAL NO	YEAR	NAME OF AUTHOR	TOPIC NAME	FINDINGS
1.	2012	Deepak, S., Niranjan-Raj, S., Lavanya, S. N., & Mithofer Axel, S. S. H	Nutritional Bio-fortification in Pearl Millet	Bajra is gluten free, which helps people who are suffering from CD.

2.	2016	Jukanti, A. K., Gowda, C. L., Rai, K. N., Manga, V. K., & Bhatt, R. K.	Pearl Millet ( <i>Pennisetum glaucum</i> L.): an important source of food security, nutrition and health in the arid and semi-arid tropics.	<ul style="list-style-type: none"> <li>As iron deficiency is a worldwide problem, a high Fe contained pearl millet has been developed by IDRISAT along with NARS partners.</li> <li>Pearl millet is ideal for celiac patients as its gluten free</li> </ul>
3.	2019	Nithiyantham, S., Kalaiselvi, P., Mahomoodally, M. F., Zengin, G., Abirami, A., & Srinivasan, G.	Nutritional and functional roles of millets—A review	<ul style="list-style-type: none"> <li>Phytonutrients and vitamins present in millet exhibits anti-inflammatory effects</li> <li>Its gluten free and great substitute for CD patients.</li> <li>Pearl millet is rich in iron (7.5-16.9mg)</li> </ul>
4.	2021	Hassan, Z. M	The nutritional use of millet grain for food and feed	Millets being gluten free help in reducing celiac disease by reducing the irritation usually caused by the gluten containing crops and products.
5.	2015	Malik, S	Pearl millet-nutritional value and medicinal uses	<ul style="list-style-type: none"> <li>Due to its antiallergic property and gluten free nature its helpful in treating celiac disease</li> <li>Due to its high iron (8mg/100gm) and zinc (3.1mg/100gm) it help in increasing hemoglobin level in anemic patients .</li> </ul>
6.	2017	Patni, D., & Agrawal, M	Wonder millet-pearl millet, nutrient composition and potential health benefits-a review.	<ul style="list-style-type: none"> <li>Pearl millet contains high iron and zinc help in increasing hemoglobin level</li> <li>Pearl millet have high potential in preparing</li> </ul>

				foods and beverages that will be gluten free and suitable for celiac patients.
7.	2022	Gupta, V., Singh, A. P., & Gupta, N	Importance of pearl millet and its health benefits	<ul style="list-style-type: none"> <li>• Help in increasing Hb in anemic patients</li> <li>• Its helpful foe celiac patients as its gluten free.</li> </ul>
8.	2021	Anitha et al.	Millets can have a major impact on improving iron status, hemoglobin level, and in reducing iron deficiency anemia—a systematic review and meta-analysis	<ul style="list-style-type: none"> <li>• Study showed that pearl millet-based meal increased bioavailable iron</li> <li>• Also showed that millet can reduce iron deficiency anaemia.</li> </ul>
9.	2022	Mishra et al.	Nutritional Values And Potential Health Benefits of Millets -A	<ul style="list-style-type: none"> <li>• Gluten free diet is the solution for celiac disease, and millet based foods and beverages are best option for them.</li> </ul>
10.	2015	Finkelstein et al.	A randomized trial of iron-biofortified pearl millet in school children in India	<ul style="list-style-type: none"> <li>• Iron fortified pearl millet improved the iron status in children, within 4 months compared to control pearl millet.</li> </ul>
11.	2011	Nambiar et al.	Potential functional implications of pearl millet (Pennisetum glaucum) in health and disease	<ul style="list-style-type: none"> <li>• Pearl millet increases the Hb level also promotes gluten free nature ideal for celiac patients.</li> </ul>
12.	2022	Mehta et al.	A randomized trial of iron-and zinc-biofortified pearl millet-based complementary feeding in children aged 12 to 18 months living in urban slums	<ul style="list-style-type: none"> <li>• FeZn fortified pearl millet, significantly improved iron status in male child who were Hb deficient or Hb-depleted at base line.</li> </ul>

13.	2018	Scott et al.	Cognitive performance in Indian school-going adolescents is positively affected by consumption of iron-biofortified pearl millet: a 6-month randomized controlled efficacy trial.	<ul style="list-style-type: none"> <li>• this study indicated, iron fortified pearl millet improved iron status among Indian boys and girl.</li> </ul>
14.	2013	Cercamondi et al.	Total iron absorption by young women from iron-biofortified pearl millet composite meals is double that from regular millet meals but less than that from post-harvest iron-fortified millet meals	<ul style="list-style-type: none"> <li>• Iron bio fortified pearl millet doubles the amount of iron absorbed, in the body</li> </ul>
15.	2023	Tripathi et al.	A review on nutritional and health benefits of millets	<ul style="list-style-type: none"> <li>• Millets are excellent source of different nutrients.</li> <li>• Pearl millet is rich in iron and fibre.</li> <li>• Its gluten free nature makes its suitable for individual suffering from celiac disease.</li> </ul>
16.	2023	Anagha & K. K	Millets: Nutritional importance, health benefits, and bioavailability: A review.	<ul style="list-style-type: none"> <li>• Pearl millet is an excellent source of iron, thus help in Hb and RBC formation.</li> <li>• Gluten free and excellent option for celiac patients</li> </ul>
17.	2010	Saturni et al.	The gluten-free diet: safety and nutritional quality	<ul style="list-style-type: none"> <li>• Study reveals that due to celiac disease there is episode of iron deficiency anemia from 12-69%.</li> </ul>
18.	2021	Satyavathi et al.	Pearl millet: a climate-resilient nutricereal for mitigating hidden hunger	<ul style="list-style-type: none"> <li>• In India people are suffering from IDA, so here biofortification of staple crops are ideal to</li> </ul>

			and provide nutritional security.	<p>treat micronutrient deficiency</p> <ul style="list-style-type: none"> <li>• Being gluten free its extremely useful for people who are suffering from celiac disease.</li> </ul>
19.	2008	Srivastava et al.	Development of multi-nutritional health biscuits from pearl millet processing	<ul style="list-style-type: none"> <li>• Gluten free pearl millet flour biscuits were developed, which contains high energy, protein, fat, fibre and iron, phosphorus, calcium.</li> </ul>
20.	2022	Gulia et al.	Evaluation of pizza base prepared with pearl millet and Chia seeds: A healthy alternative.	<ul style="list-style-type: none"> <li>• Gluten free pizza base was prepared using pearl millet with chia seeds. which contained high protein, fibre, calcium, and iron.</li> </ul>
21.	2015	Brasil et al.	Physical, chemical and sensory properties of gluten-free kibbeh formulated with millet flour ( <i>Pennisetum glaucum</i> (L.) R. Br.	<ul style="list-style-type: none"> <li>• Pearl millet kibbeh having more protein and dietary fibre was prepared, making them great option for celiac patients.</li> </ul>
22.	2023	Selladurai et al.	Considerations for gluten free foods-pearl and finger millet processing and market demand.	<ul style="list-style-type: none"> <li>• They studied about different pearl millet product with addition of different products.</li> <li>• food blend, cookies, were rich in different nutrients</li> </ul>
23.	2004	Khatkar et al.	Impact assessment of processing of pearl millet for value-addition and development of health foods.	<ul style="list-style-type: none"> <li>• This study revealed that partial replacement of basic ingredients with pearl millet eventually beneficial both in a monetary way and nutritional value</li> </ul>



24.	2021	Kulkarni et al.	Studies on development of low gluten cookies from pearl millet and wheat flour	<ul style="list-style-type: none"> <li>• Cookies made from 100% pearl millet has higher nutrients</li> </ul>
25.	2014	Pradeep et al.	Formulation and nutritional evaluation of multigrain ready-to-eat snack mix from minor cereals	<ul style="list-style-type: none"> <li>• A ready to eat snack mixture prepared from popped pearl millet has high nutrient content.</li> </ul>
		Georgina et al.	Effect of Consumption of Sourdough Pearl Millet ( <i>Pennisetum Glaucum</i> ) Snack on the Hemoglobin and Zinc status of School-Age Children in Odeda Local Government Area, Ogun State, Nigeria	<ul style="list-style-type: none"> <li>• Sour dough pearl millet extruded snack increased the Hb status in anemic children.</li> </ul>
				•
26.	2018	Krishnan et al.	Pearl millet minerals: effect of processing on bioaccessibility.	<ul style="list-style-type: none"> <li>• Study revealed the feeding children with iron and zinc biofortified pearl millet help in combating many micronutrient deficiencies.</li> <li>• Alkaline soaking improves bioaccessibility of iron by 2.5% in endosperm fraction</li> <li>• Fermentation increases zinc and iron absorption</li> <li>• Combination of different treatments helps in reducing inhibitory factors and nutrients retention</li> <li>• Pearl millet has the potential to use as a dietary component to</li> </ul>

				manage nutrient deficiencies
27.	2016	Vanishree et al.	Development and evaluation of pearl millet based novel health drink.	<ul style="list-style-type: none"> <li>• Iron rich health drink was prepared by using bajra and different food ingredients for fortification, for combating anemia.</li> <li>• Germination enhanced it mineral and protein content.</li> </ul>
28.	2013	Saleh et al.	Millet grains: nutritional quality, processing, and potential health benefits	<ul style="list-style-type: none"> <li>• Study showed, germination increased, bioaccessibility of different minerals.</li> <li>• Fortification of pearl millet is cost effective way to prevent micronutrient deficiency.</li> <li>• Millet grains and their fractions have potential to prevent celiac disease.</li> </ul>
29.	2014	Moreno Amador et al.	Alternative grains as potential raw material for gluten-free food development in the diet of celiac and gluten-sensitive patients	<ul style="list-style-type: none"> <li>• Iron supplementation in bajra would be an advantage in people who are suffering from IDA in celiac patients</li> </ul>
30.	2014	Rai et al.	Quality characteristics of gluten free cookies prepared from different flour combinations	<ul style="list-style-type: none"> <li>• Cookies prepared with pearl millet and sorghum flour was nutrient dense</li> </ul>
31.	2022	Mishra &S	Physicochemical Properties and Microstructure of Ready-To-Eat (RTE) Breakfast Cereal Made from Popped Pearl Millet, Amaranth	<ul style="list-style-type: none"> <li>• Breakfast cereal developed by popped pearl millet, popped amaranth grain and ground nut powder. These grains being rich in iron and zinc is</li> </ul>

			Grains and Groundnut Powder.	useful for celiac and anemic patients.
32.	2016	Johari et al.	Development of Value-Added Pearl Millet and Rice-Based Gluten Free Porridge	<ul style="list-style-type: none"> <li>• Pearl millet , rice based gluten free porridge was made with value addition pf sesame seeds, amaranth and soyabean. This can be ideal for celiac patients</li> </ul>
33.	2018	Gomathi et al.	QUALITY EVALUATION AND FORTIFICATION OF IRON RICH COOKIES USING MILLETS.	<ul style="list-style-type: none"> <li>• Iron rich millet cookies were prepared to evaluate their nutritional quality</li> </ul>
34.	2019	Kumari et al.	Development of healthy ready-to-eat (RTE) breakfast cereal from popped pearl millet	<ul style="list-style-type: none"> <li>• Ready to eat breakfast cereal was developed by popped pearl millet, and mixing different products. product made was nutrient rich.</li> </ul>
35.	2017	Adebiyi et al.	Comparison of nutritional quality and sensory acceptability of biscuits obtained from native, fermented, and malted pearl millet ( <i>Pennisetum glaucum</i> ) flour	<ul style="list-style-type: none"> <li>• Malting and fermentation, improved, mineral composition of PMF and biscuit which can be helpful in treating children with mineral deficiencies.</li> </ul>
36.	2014	Suma et al.	Nutrients, antinutrients & bioaccessible mineral content (invitro) of pearl millet as influenced by milling.	<ul style="list-style-type: none"> <li>• Semirefining of flour improved the bioaccessibility of iron and calcium (invitro).</li> </ul>

## METHODOLOGY

NAME OF THE METHODS	DESCRIPTION
1. SOAKING	THIS IS A POPULAR HOUSEHOLD METHOD USUALLY USED FOR REDUCING THE ANTINUTRIENTS NAMELY PHYTIC ACID AND PHYTASE ACTIVITY WHICH IN ORDER IMPROVE BIOAVAILABILITY OF MINERALS LIKE IRON AND ZINC.

<p><b>1. GERMINATION</b></p>	<p><b>IN MILLETS, THIS PROCESS DECREASES THE LEVELS OF TANNINS, IN PEARL MILLET PROTEIN AND STARCH DIGESTIBILITY, IT ALSO HELPS IN THE REDUCTION OF DIFFERENT ANTINUTRIENTS PRESENT.</b></p>
<p><b>2. FERMENTATION</b></p>	<p>It is mostly used for preservation purposes, also improves the nutritional properties of raw foods. In pearl millet, this improves nutrient value like ash, fat, protein, fiber and moisture. It also increases the absorption of iron and zinc by production of low molecular weight organic acids.</p>
<p><b>3. POPPING</b></p>	<p>Here sand is used as heat transfer media with high temperature short time method, that gradually result in starch gelatinization and the endosperm burst gives a desirable flavor &amp; aroma.</p> <p><b>(Sarita et al. 2016)</b></p>
<p><b>4. FORTIFICATION</b></p>	<p>It's an effective way to combat with different nutrient deficiency disorders</p>
<p><b>5. BLANCHING</b></p>	<p>It's an effective preservation technique, it's been studied that, water blanching and dry heating of pearl millet can minimize the undesirable changes occur in pearl millet meals during storage.</p>
<p><b>6. DEPIGMENTATION</b></p>	<p>It's been studied that depigmentation of pearl millet is an effective way, for developing pearl millet products with better in vitro protein and starch digestibility.</p> <p><b>(Saleh et al. 2013)</b></p>
<p><b>7. HYDROTHERMAL TREATMENT</b></p>	<p>It's been showed better bioaccessibility of different nutrients. A recent study showed, reduction in phytic acid and polyphenol in bajra.</p>
<p><b>8. DECORTICATION</b></p>	<p>This method of processing also reduced the phytic acid and polyphenol in bajra while increasing the bioaccessibility.</p> <p><b>(Krishnan et al. 2018)</b></p>
<p><b>9. RANDOMIZED CONTROL TRIAL METHOD</b></p>	<p>Gold standard for clinical evidence to determine the true relative efficacy of an intervention.</p>

	(Mehta et al. 2022)
<b>10. IGA ANTITRANSGLUTAMINASE ANTIBODY, ANTI-ENDOMYSIAL AND ANTI-GLIADIN ANTIBODY TEST</b>	Tests done for diagnosing celiac patients.  (Nijhawan et al.2013)
<b>11. ATOMIC ABSORPTION SPECTROPHOTOMETER</b>	Use in determining amount of different minerals present in samples of developed products.
<b>12. MALTING</b>	Which is limited germination of cereals, under moist control condition. it's been showed this process enhances the starch and protein digestibility in bajra.  (Rathore et al. 2016)
<b>13. SENSORY ANALYSIS</b>	Appearance, test, color, odour, texture, and overall acceptability is measured based on the evaluation.  (Ransilu et al. 2019)
<b>14. ALPHA, ALPHA DIPYRIDYL METHOD</b>	Is used to determine available iron present in developed product.  (Gulia et al. 2022)

**RESULT AND DISCUSSION**

▪ **Proximate analysis of pearl millet (g/100g)**

Nutrients	Pearl millet
Moisture	12.4
Protein	11.6-11.8
Fat/lipids	4.8-5.0
Dietary fibre	11.3
Neutral detergent fibre	9.0
Acid detergent fibre	3.3
carbohydrates	67-67.5
Gross energy (MJ/kg)	17.0
Minerals(mg/100g)	
phosphorus	296
potassium	307
magnesium	137

calcium	42
sodium	10.9
zinc	3.1
iron	8.0
manganese	1.15
copper	1.06

(Hassan et al. 2021)

Table no-1

▪ NUTRITIVE VALUE OF PEARL MILLET PRODUCT

NAME OF THE PRODUCT	NUTRIENT	AMOUNT	ADVANCEMENTS & LIMITATION
1. Multi-nutritional health biscuits	<ul style="list-style-type: none"> <li>• Energy</li> <li>• Protein</li> <li>• Fat</li> <li>• Fibre</li> <li>• Iron</li> <li>• Phosphorus</li> <li>• calcium</li> </ul>	<ul style="list-style-type: none"> <li>• 448-488 kcal</li> <li>• 7.8-8.5g</li> <li>• 16-22g</li> <li>• 2.5g/100g</li> <li>• 2.7 mg %</li> <li>• 1600 mg%</li> <li>• 604mg%</li> </ul>	<p>There is, no limitation, pearling improved the shelf life of the biscuits.</p> <p><b>(Srivastava et al.2008)</b> Table no-2</p>
2. Pizza base prepared with pearl millet and fortified with chia seeds	<p>▪ 3 bases were made with, 3 different ratio of ,</p> <p>pearl millet :chia seeds</p> <ul style="list-style-type: none"> <li>• Protein</li> <li>• Fibre</li> <li>• Calcium</li> <li>• Iron</li> </ul>	<p>12.25-14.42g/100g</p> <p>10.62-15.13g/100g</p> <p>99.19-197.39mg/100g</p> <p>5.32-5.51mg/100g</p>	<p>No limitations were present, also incorporation of chia seeds improved nutritional profile and also helped in baking due to its unique physiochemical properties.</p> <p><b>(Gulia et al. 2022)</b> Table no-3</p>
3. gluten free kibbeh prepared	<ul style="list-style-type: none"> <li>• Moisture</li> <li>• Lipids</li> <li>• Ashes</li> </ul>	<p>55.91± 2.04g</p> <p>12.51 ±1.76g</p> <p>2.80± 0.27g</p>	<p>They presented, good oxidation stability.</p>

with millet flour			<p><b>(Brasil et al. 2015)</b>  <b>Table no-4</b></p>
<p><b>4. Low gluten cookies from pearl millet and wheat flour</b></p>	<ul style="list-style-type: none"> <li>• Cookies were prepared by substituting whole wheat flour with pearl millet flour(PMF) at different percentage. (20%,40%,60%,80%, and 100%)</li> <li>• calcium</li> <li>• phosphorus</li> <li>• iron</li> </ul>	<p>18.26±0.01-22.75 ±0.04 mg/100g</p> <p>86.76±0.01-197.18±0.04mg/100g</p> <p>2.48 ±0.03 -4.84±0.02 mg/100g</p>	<p>The proteins and carbohydrate content were found to be decreased with increasing levels of PMF , in cookies</p> <p><b>(Kulkarni et al. 2021)</b>  <b>Table no-5</b></p>
<p><b>5. multigrain ready to eat snack mix</b></p>	<p>Moisture content  Protein  Ether extractives  Calcium  Magnesium  Iron  Zinc  Free sugar</p>	<p>5.1g/100g  14g/100g  14.5g/100g  219.3mg/100g  49mg/100g  6.6mg/100g  4.13mg/100g  30g/100g</p>	<p>Limitation includes, high in free sugar content.</p> <ul style="list-style-type: none"> <li>• Despite that popping increased protein and carbohydrate digestibility, also lower moisture content help in better shelf life.</li> </ul> <p><b>(Pradeep et al. 2014)</b>  <b>Table no-6</b></p>

<p><b>6. Pearl millet based health drink</b></p>	<p>Sprouted, and then popped millet flour was fortified with other products at different percentage (50%, 60%, 70%, 80%, 100%) to make this drink. Effect of fortification on nutrient composition of malted Bajra:-</p> <ul style="list-style-type: none"> <li>• Carbohydrate-</li> <li>• Protein</li> <li>• Fat</li> <li>• Ash</li> <li>• Moisture</li> <li>• Fiber</li> <li>• Iron</li> </ul>	<p>66.98-67.48g 15.43-14.55g 4.96-3.93g 2.25-1.92g 9.56-9.21% 2.23-1.5g  9.3-8.5mg</p>	<p>Fortification with other products like ragi, soya, sugar powder, skimmed milk powder, helped in enhancing nutritional profile.</p> <p><b>(Vanishree et al. 2016)</b></p> <p><b>Table no-7</b></p>
<p><b>7. Ready to eat popped pearl millet breakfast cereal</b></p>	<p>Energy (kcal) Carbohydrate (g) Protein(g) Total dietary fiber (%) Fat(g) Iron(mg) Calcium(mg) Phosphorus(mg) Zinc(mg) Vitamin E(mg) Folic acid(mg) Niacin(mg)</p>	<p>422.4 78.3 9.34 6.13 8.26 5.02 62.79 239.53 3.24 3.86 103.21 390</p>	<p>Breakfast cereal was fortified with amaranth, puffed wheat, flax seed, sunflower seed, raisins, honey, sugar, and oil which made it nutritional profile better than many market popular breakfast cereals.</p> <p><b>(Kumari et al.2019)</b></p> <p><b>Table no-8</b></p>

**RESULT AND DISCUSSION**

**FINDINGS:**

- Various products were developed using pearl millet, which included -cookies, pizza base, kibbeh, health drink, ready to eat breakfast cereal, ready to eat snack mix and biscuits with different nutritional profile.



- Various processing techniques were used, which improved their nutritional composition, increased bioaccessibility, also reduced antinutritional properties.
- products also showed improved shelf life and oxidation stability.
- Based on processing treatments there was, decrease in certain macronutrients in one study

**Enriching pearl millet-based products:**

For enhancement of certain nutrients, in various study pearl millet was fortified using different products, they are:

- **Seeds:** flax seed, sesame, sunflower and chia seeds are used multiple times.
- Other cereals and legumes: - ragi, soya
- Skimmed milk powder, raisins, sugar, and honey are also used for taste enhancement
- Oil has also been used, to make it more calorie dense

**RESULT AND DISCUSSION ( iron deficiency anaemia in celiac disease)**

1. A pioneer study also conducted which resulted in iron, vitamin D, zinc, magnesium, vitamin B12 and folate deficiency in untreated celiac patients.
  - Iron deficiency anaemia is present in 7-81%of the patients during diagnosis also is common in adults &women (**Caruso et al.2013**)
2. Another systematic review and meta-analysis,
  - studied the prevalence of 1 out of 31 patients with iron deficiency anaemia have histologic evidence of celiac disease that also justifies of the need to test patients with iron deficiency anaemia for celiac disease (**Mahadev et al.2018**)
3. Another study revealed that iron deficiency anaemia is the most common type of anaemia present in celiac patients (**Stefanelli et al.2020**)
4. Another study revealed that iron deficiency anaemia is frequently found in celiac patients, 10-20%of the cases. (**Martín-Masot et al.2019**)
5. This study suggests that iron deficiency anaemia is a significant cause of celiac disease in both adults and children. (**Freeman &H. J. 2015**)
6. Another study also studied how celiac patients can also suffer from osteoporosis, irritable bowel syndrome, diarrhea, another auto immune diseases like type-1 diabetes, thyroid disease, auto immune liver diseases (**Green & P. H. 2005**)
7. Another study also studied different clinical phenotype of celiac patients including constipation, anaemia, osteoporesis, neurologic disorders in 52%patients, diarrhoe, weight loss in 27% patients (**Caio et al.2019**)

<b>COMPONENTS OF PEARL MILLET AND ITS DERIVED PRODUCTS</b>	<b>POTENTIAL BENEFITS ON CELIAC AND ANAEMIC PATIENTS and other associated diseases with celiac</b>
1. Iron	Bajra itself and its products are rich in iron, which help in iron deficiency anaemia
2. Phosphorus	High amount of phosphorus, helps in bone growth and development in kids

○ Dietary fiber	High dietary fibre, helps in slow release of glucose which maintains blood sugar level and is also suitable for diabetes patients
○ Hypoallergic properties	Makes it appropriate choice for infants, aged people, convalescents and also for lactating mothers.
○ Magnesium	It helps in reducing respiratory issues.
○ Potassium	High amount of magnesium and potassium helps in, managing blood pressure and in treating heart disease <b>(Srivastava &amp; S. 2021)</b>
3. Gluten free and Higher prolamin fraction	<ul style="list-style-type: none"> <li>• Bajra is gluten free and is having higher prolamin fraction which makes it ideal option for celiac patients</li> <li>• Also this paper suggests semi refining of pearl millet reduces the phytate content and also improves in vitro bioaccessibility of Fe and Ca <b>(Gowda et al.2022)</b></li> </ul>
4. Glycemic index	<ul style="list-style-type: none"> <li>• Low in glycemic index, make it suitable for those who is suffering from diabetes or tend to be affected by diabetes</li> <li>• Also being gluten free make bajra ideal for commercialization</li> </ul>
5. Omega 3 fatty acid	<ul style="list-style-type: none"> <li>• Pearl millet is having higher percentage (linoleic acid accounts for 4% of the total fatty acids in this) which plays an important role in platelet aggregation, accumulation of LDL cholesterol, and in improving immune system. <b>(Rai et al.2008)</b></li> </ul>
6. Phytochemicals like phenolic acids and flavonoids	<ul style="list-style-type: none"> <li>• It helps in overall health management.</li> </ul>
7. Nutraceuticals	<ul style="list-style-type: none"> <li>• It helps in preventing disease risk, also helps as prebiotic and probiotic anti diabetic, anti tumorigenic. <b>(Ambati et al.2019)</b></li> </ul>
8. Polyphenols	<ul style="list-style-type: none"> <li>• Shown their effect on reducing sickle cell anemia, neurodegenerative and cardio vascular diseases. <b>(Akanbi et al.2019)</b></li> </ul>

## APPLICATION:

Based on the findings we came to about many papers which are recommending pearl millet being gluten

free is suitable for celiac patients, at the same time they are antiallergic.

Pear millet being high in iron and zinc is helpful in increasing hemoglobin levels.

Findings also support how millet-based meals increased bioavailable iron, also showed it can improve iron deficiency anaemia.

- For celiac patients' gluten free diet is the only option, pear millet-based diets will improve their health status overall.
- Celiac patients not only suffer from iron deficiency, but also, they also come across different other auto immune disease, like type 1 diabetes, lower immunity, neurodegenerative diseases etc. pearl millet can be a savior for these patients.
- Food manufactures should take help from health providers and researcher in order to enrich and fortify Pearl Millet rich foods
- Also incorporating several seeds (flaxseeds, pumpkin seeds, chia seeds), dried fruits dates, blueberries, raspberries), nuts (walnuts, brown raisins, almonds etc.), dried leaves (amaranth), natural flavors, and essence in different products will decrease the boredom of the patients and will make it more appetizing.
- Applying natural food colors will also, make bajra product appetizing cause its off color is some time make it unacceptable to consumers.
- Health care providers and academicians should be enthusiasts and empathetic towards these patients, and teach, demonstrate them the effectiveness of pearl millets and other millet in improving health status.

#### **Future perspective:**

1. New processing techniques to improve, its shelf life & bioavailability and inaccessibility.
2. Different techniques like soaking, germination, popping, malting, fermentation to decrease antinutrients.
3. Bio fortification, fortification, enrichment with different minerals and others to enhance nutrient content.
4. Agricultural techniques, processing organic fertilizers to improve crop yield.
5. Different policies to promote millet as sustainable crop.
6. Organizing and establishing hypothesizes, on human health by conducting well designed trials .
7. More research on heat treatment (hydrothermal, microwave, ohmic heating), cold plasma to remove rancidity and off Flavors .

#### **Conclusion**

Millet, often referred to as the "poor man's crop," is nutritionally superior to many popular grains. With the increasing global population, millets are gaining recognition for their nutritional benefits, as they are gluten-free and possess phytochemical properties that can enhance the health of individuals with celiac disease. In developing nations like India, the demand for gluten-free foods and beverages is rising, driven by the global increase in gluten allergies. Despite the promising nutritional value of pearl millet, which is an excellent source of micronutrients and can significantly improve iron status in celiac patients, its production and consumption remain limited.

The lack of innovative product development and utilization means that various potential applications of Bajra remain unexplored. Additionally, there is a deficiency in the technologies and initiatives necessary to fully leverage this sustainable crop. Current methods for preservation, processing, and utilization of

millet are inadequate, preventing its widespread adoption. Advanced technologies and comprehensive research are required in several areas of millet study, including preservation techniques, improving the bioavailability of its nutrients, and understanding the phytochemical activities of millet in managing different physiological conditions.

Moreover, there is a significant opportunity to develop gluten-free, nutrient-dense products from pearl millet. Such products would not only meet the dietary needs of individuals with celiac disease but also provide a healthy alternative for the general population. Future studies should focus on exploring these avenues, as well as developing efficient methods for cultivating, harvesting, preservation, bioaccessibility and processing pearl millet to enhance its accessibility and appeal. By addressing these challenges, we can promote the broader use of pearl millet, contributing to food security, nutritional improvement, and economic development, especially in regions where it is most needed.

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