www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(5): 304-308

www.thepharmajournal.com
Received: 10-03-2022
Accepted: 14-04-2022

**Shweta Singh**
Department of Food Process Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

**Dr. Ajay Kumar Singh**
Department of Food Process Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

**Kunal Singh**
Department of Food Process Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

**Baljor Singh**
Department of Food Process Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

**Corresponding Author**
**Kunal Singh**
Department of Food Process Engineering, SHUATS, Prayagraj, Uttar Pradesh, India

# Millets processing, nutritional quality & fermented product: A review

**Shweta Singh, Dr. Ajay Kumar Singh, Kunal Singh and Baljor Singh**

**Abstract**

**Purpose:** Pearl millet (*Pennisetum glaucum*) is a rich source of nutrients as compared to the major cultivated cereal crops. However, major factors which limit its utilization are the presence of anti-nutritional factors (phytate, tannins and polyphenols) which lower availability of minerals and poor keeping quality because of higher lipase activity. Therefore, this paper aims to focus on the impact of different processing methods on the nutrient composition and anti-nutritional components of pearl millet.
**Design/methodology/approach:** This is a literature review study from 1983 to 2017, focusing on studies related to pearl millet processing and their effectiveness in the enrichment of nutritional value through reduction of anti-nutritional.
**Findings:** From the literature reviewed, pearl millet processing through various methods including milling, malting, fermentation, blanching and acid as well as heat treatments were found to be effective in achieving the higher mineral digestibility, retardation of off flavor, bitterness as well as rancidity problems found during storage of flour. Through this review paper, possible processing methods and their impact on the nutrient and anti-nutrient profile of pearl millet are discussed after detailed studied of literature from journal articles and thesis.

**Keywords:** Fermentation, processing, pearl millet, dehulling, anti-nutritional factors

## Introduction

Millets are nutritionally rich and occupy an important place in the diet of people in many regions of the world. Although millets are nutritionally superior to cereals their utilization as a food is still mostly confined to the traditional consumers and population of lower economic strata. The special features of the millets, their beneficial uses and health consciousness of the consumer have made food scientists and engineers to develop various food products and mechanize the processes. There are various traditional and convenience foods including ready-to-eat (RTE) food products developed from millets. Millet is predominately starch rich with the protein component being compatible to that of sorghum, wheat and corn. Millets are high in fiber and can be as high as 20% of the overall grain composition. Millet is a generic term used for small sized grains that form heterogeneous group and referred along with maize and sorghum as 'coarse cereals'. Their agricultural importance arises from their hardiness, tolerance to extreme weather and could be grown with low inputs in low rainfall areas.

Pearl millet (*Pennisetum glaucum)* indicates that it is a good source of energy, protein, vitamins and minerals (Osman 2009) [18]. However, bioavailability of the nutrients is restricted due to the presence of anti-nutritional factors such as phytic acid, tannins, goitrogens, oxalic acid and trypsin inhibitors. These compounds interfere with mineral bioavailability, carbohydrates and protein digestibility through inhibition of proteolytic and amylolytic enzymes. The phytic acid is present in the germ whereas, polyphenols are in peripheral areas of the pearl millet grain (Simwemba *et al*. 1984) [38]. Phytic acid has a strong ability to chelate multivalent metal ions, specially zinc, calcium, iron and as with protein residue. The binding can result in insoluble salts with poor bioavailability of minerals (Coulibaly *et al.* 2011) [51]. Hence, it is important to reduce the phytic acid and polyphenols to avail the nutritional benefits of this grain. Pearl millet grain is light in weight (3-15mg) but has a proportionally larger germ (17.4%) than all other cereal grains, except maize (Taylor 2004) [27]. It contains a higher content of triglycerides, which are rich in unsaturated fatty acids. Pearl millet flour used for food preparation like *roti* (flat bread), *bhakri* (stiff *roti*) and porridge or gruel is produced by milling, either through traditional or mechanical processes. However, pearl millet flour turns bitter and rancid within a few days of storage period, due to lipolysis and subsequent oxidation of the resulting de-esterified unsaturated fatty acids (Lai and Varriano-Marston

1980) [26]. *Bajra* or pearl millet (*Pennisetum americanum*), *ragi* or finger millet (*Eleusine coracana*), *navane* or foxtail millet (*Setaria italica*), *samai* or little millet (*Panicum miliare*),*haraka* or kodo millet (*Paspalum scrobiculatum*), *panivaragu* or proso millet (*Panicum miliaceum*), banti or barnyard millet (*Echinochloa frumentacea*) are the important millets cultivated largely in the Asian and African countries. R.V. Jaybhaye (2014) [29].

**Methods**

Extrusion technology has been widely used in the preparation of cereal-based snack products. Extrusion is believed to yield safe foods that have a long shelf life; hence extrusion is a useful, economical processing technology to prepare food products and to manage food scarcity during drought conditions. Due to its versatility, low cost, efficiency, product quality and eco-friendliness, extrusion has been in wide use during the past two decades. Extrusion-cooking parameters, such as barrel temperature (BT), screw speed, moisture content, die diameter, and feed rate, have been reported to influence the physio-chemical characteristics of extrudates. Extrusion cooking has some unique features compare to other heat processes. It is capable of breaking covalent bonds in biopolymers and facilitating reactions otherwise limited by diffusion of reactants and products (Iwe *et al.*, 2001). Extrusion alters the nature of many food constituents, including starches and proteins, by changing their physical, chemical and nutritional properties. High temperature short time (HTST) extrusion cooking technology has limitless applications in processing of cereal based products. Extrusion cooking is a popular means of preparing snacks and ready to eat foods. Extrudates are microbiologically safe, can be stored for long periods because of low moisture without need for refrigeration and requires less labour for handling and less packaging materials and storage space (Filli and Nkama, 2007). Fermentation is one of the processes that decreases the level of antinutrients in food grains and increases the starch digestibility, protein digestibility and nutritive value. The nutritional evaluation of fermented grains has been examined by many workers. Fermentation also leads to an increase in protein content, enhancement of carbohydrate accessibility, improvement in amino acid balance, decrease in antinutritional factors like tannin and phytic acid. Household fermentation technologies have been upgraded to an industrial scale in order to provide value added products that meet urban population demand for traditional products. (Singh *et al.*, 2012) [47].

Processing of millets had yielded promising results in their successful utilization for various traditional as well as convenience health foods. Accordingly different researchers have tried to develop processed products like popped, flaked, puffed, Extruded and roller dried products; fermented, malted and composite flours; weaning foods, etc. For example, exploratory studies on popping and milling of millets have been promising (Malleshi, 1986) [53]. Extrusion of weaning foods of pearl millet increases the protein digestibility (Cisse *et al.*, 1998) [52] whereas germination and probiotic fermentation causes significant improvement in protein profile and in-vitro mineral availability. Probiotics aid the existing flora, or help repopulate the colon when bacteria levels are reduced by antibiotics, chemotherapy or disease. FAO/WHO stated that probiotics are "lives microorganisms which when administered in adequate amounts confer a health benefit on the host" though, this should also specify genus, species and strain level, as well as a safety assessment. Most of probiotic foods generate fatty acids, vitamins and other vital nutrients that improve the body's resistance against pathogens microorganisms**.** (Arora *et al*., 2011) [40].

**Fermentation**

Functional and nutritional aspects of fermentation have been widely studied in commonly consumed cereals and legumes. There is, however, limited information on the functional properties of fermented Amaranth and Buckwheat flour and this information is essential for determining potential uses of these products in food formulation.

If fermentation is accomplished with probiotic organisms, it can bring specific added advantages apart from the nutritional improvement. Probiotics are defined as "live microorganisms, which when administered in adequate amounts confer health benefits on the host" (Sanders, 2003). Specific bacteria, especially the species of lactobacilli compose the majority of recommended probiotics (Goldin & Gorbach, 1992) [35]. In addition to their nutritional benefits during fermentation, probiotic organisms have positive effects on metabolism improvement, constipation reduction, and cholesterol level reduction (Fukushima & Nakano, 1996 ;Sindhu & Khetarpaul, 2001) [34, 33].

Prebiotics are defined as non-digestible food components that when they are administered in sufficient amount can selectively stimulate the growth and activity of one or a number of microbes in the colon (Crittenden & Playne, 1999). Therefore, prebiotics are necessary for viability and vitality of the probiotics. The mixture of probiotics and prebiotics results into a new family of functional foods, called synbiotic products (Roberfroid, 1998; Schrezenmeir & de Vrese, 2001) [37]. Pearl millet has a relatively better mineral profile but the availability of the increasing privatisation of the Indian seed industry has not been met with universal enthusiasm. In particular, the research focus on proprietary hybrids has aroused a public debate about the potential social implications in the small farm sector. For example, it is argued that privately developed seeds would further marginalise smallholders by primarily benefiting large commercial farms with sufficient resources to afford higher input requirements (Shiva and Crompton, 2002). Furthermore, it is feared that farmers might be exploited by private companies charging excessive prices for proprietary seeds. And finally, concerns are raised that restricted access will 'slow down the diffusion of modern technologies as farmers will find it increasingly difficult to propagate, sell or exchange seeds' (Srinivasan and Jha, 2002, p. 108). A decline in diffusion rates of modern seed technologies would have grave consequences for agricultural productivity and economic growth in rural areas.

Studies that addressed some of these concerns with respect to pearl millet in India include Pray and Ramaswami (2001) and Ramaswami *et al*. (2002) [30, 31]. They showed that private hybrids have a significant yield advantage over open-pollinated varieties (OPVs) as well as over public hybrids, and that district-level yield variations were reduced. Pray *et al*. (1991) [32] established that farmers reap a considerably larger share of the benefits from hybrid pearl millet cultivation than seed companies. Similar results were also obtained by Matuschke *et al*. (2007) for hybrid wheat in India. Yet, none of these studies looked into longer term adoption dynamics, which are important for an understanding of the wider social ramifications. This issue is addressed in the present study. In particular, we aim to establish the determinants of hybrid pearl millet adoption and the impact of the increasing privatisation on technology diffusion. The analysis is based on a comprehensive survey of 266 pearl millet farmers in the state of Maharashtra in the semi-arid tropics of India. The survey data comprise information on household characteristics, pearl millet production and farmers' individual adoption histories. Duration analysis, therefore, allows us to determine not only why farmers adopted hybrid pearl millet, but also when they adopted and what factors influenced the observed time patterns. Apart from shedding light on the role of the private sector in the innovation process, the results can also be useful in a wider policy context. A better understanding of the underlying dynamics can help improve strategies to speed up adoption. This may be particularly interesting for private and public crop technologies that are currently in the R&D pipeline.

Processing is commonly done to enhance the quality of the grains by converting them into edible form. Utilization of millets could be enhanced by processed them into various forms like rice, flour, roasted, popped, sprouting, salted ready-to-eat grains, porridges and fermented (Jaybhaye *et al*., 2014).

**Processing**

Dehulling is the process accompanied by removal of the outer layer of the grains, hull as well as pericarp (Taylor and Duodu, 2014) [28]. In pearl millet and other small millets, fraction of husk varied from 1.5 to 29.3 per cent (Jaybhaye *et al*., 2014) [42]. Previously for household level, millets were decorticated by hand pounding. Nowadays, rice milling machines (Singh and Raghuvanshi, 2012) [45] and rice huller with polisher (Agu *et al*., 2007) [3] are commonly used for this purpose. Abrasive mill (Ayo and olawale, 2003) [41] or disks with mechanical dehullers are still used for decortication purposes. About 12 to 30 per cent of outer grain surface is removed by decortication; decortication beyond this limit causes substantial loss of ash, fat, micronutrients, fiber, proteins and amino acids such as lysine, histidine and arginine (Rai *et al*., 2008) [43]. Devisetti *et al*. (2014) [10] reported that unit operation like dehusking in a centrifugal sheller, followed by removal of bran resulted in the production of pearl and little millets grains with satisfactory quality. Central Institute of Agricultural Engineering (CIAE, ICAR), Bhopal, created a machine for pearl millet processing which has a grinding ability of 100 kg/h, at 10-12 per cent moisture content. This machine works at one horse power single phase electric motor having capacity of processing even 1 kg of grains. Moreover, husk is separated simultaneously with a suction arrangement and cyclone separator attached to the machine (Balasubramanian, 2015) [4]. Rural Industries Innovation Center (RIIC), Kane, Botswana, also manufactured a dehuller having ability of 400 to 600 kg/h which can be applied for sorghum as well as pearl millet decortication. This dehuller also has the capacity to be combined with hammer mill and thereby increases milling efficiency significantly (Rai *et al*., 2008) [43]. Effect of dehulling on nutrient composition of pearl millet was studied by several researchers, and comparison was also carried out by different decortication methods. It was reported by Serna-Saldivar *et al*. (1994) [44] that decortication done up to 17.5 per cent level showed considerable improvement in protein and dry matter digestibility. However, after decortication, higher reduction in protein, fat, insoluble dietary fiber, ash, lysine, tryptophan and other amino acids was also observed which may be due to the removal of pericarp and germ during the process of decortication. El Hag et al. (2002) [13] studied the influence of dehulling on two (Standard and Ugandi) cultivars of pearl millet. Their results showed that protein, polyphenols as well as phytic acid contents of both varieties reduced considerably after dehulling which was due to removal of outer layers. Moreover, *in vitro* protein digestibility of standard and Ugandi increased up to 79.1 and 78.6 per cent, respectively.

Increased *in vitro* protein digestibility after dehulling which was due to removal of antinutrients such as polyphenols which precipitate proteins, reduce their digestibility and also resulted in production of off-colored products. Lestienne *et al*. (2007) [23] studied the influence of abrasive decortication on the nutrient and antinutrient profile of pearl millet cultivars (Gampela and IKMP-5) which were grown mainly in Burkina Faso. Results of their study showed that abrasive decortication of pearl millet significantly decreased some antinutritional compounds (fiber and iron binding phenolic compounds) which were located in the bran of grains. However, higher phytate content after decortication might be associated with their occurrence mainly in germ and endosperm region. Hama *et al*. (2011) [17] studied the impact of manual and mechanical decortication on the nutrient composition of pearl millet (Gampela) grains and further compared it with systematized abrasive decortication method.

In this study, no significant difference was noticed between these conventional means of decortication. Minerals (iron, zinc), fiber and phytate content were reduced considerably after the traditional decortication. However, abrasive decortication carried out with tangential abrasive dehulling device resulted in higher zinc and lipid losses possibly resulted from the removal of germ during processing.

Decorticated millet can be cooked within 6 min into soft, edible grains having low hardness values. This reduction in cooking time might be associated with various factors such as smaller size, removal of seed coat, larger surface area and presence of pre-gelatinized starch in decorticated millet (Dharmaraj *et al*., 2014) [12]. From the above studies, it could be inferred that acceptability of pearl millet flour and its product can be enhanced significantly.

**Milling**

Milling is done mainly for separating endosperm, bran and germ to the maximum extent and for reduction of particles size of endosperm to facilitate the production of fine flour.

Milling of pearl millet is difficult because of its small kernel with a firmly embedded germ along with hard endosperm (Abdelrahman *et al*., 1983) [1]. Pearl millet can be milled through hammer and roller mill. Hammer mills produce a flour with larger particle size which limits its utilization for preparation of thin and stiff porridge of rough texture and also in making baked and steamed food products of smooth texture. However, these food products can be developed easily from the fine flour obtained through roller mills (Rai *et al*., 2008) [43]. Millet grains can be cooked rapidly to obtain soft texture which may be associated with higher hydration rates of milled grains. Grinding action of roller mills is also responsible for physical damage of starch granules, thereby increasing enzymatic susceptibility of starch granules (Singh and Raghuvanshi, 2012) [45]. In rural areas, domestic purpose flour is obtained by milling of grains by non-motorized grain mill that is mostly hand operated (Saleh *et al*., 2013) [49]. Recently, Central Food Technology Research Institute (CFTRI) has industrialized a new technique for enhancing the keeping quality of pearl millet flour which comprises moist heat treatment of grains followed by drying to 10-12 per cent moisture and then dehulling up to the preferred degree of pulverization is carried out. After treatment, various pearl millet varieties showed significant improvement in their milling characteristics due to high proportion of floury endosperm. Flour thus produced can be stored up to three to four months along with the advantages of maintaining free fatty acid below 10 per cent during (Rai *et al*., 2008) [43].

**Malting**

Malting is the process accompanied by restricted sprouting of cereals in humid atmosphere along with controlled set of conditions. Although protein content of the grains reduced significantly after malting, yet features such as improved protein quality and higher protein efficiency ratio make this one very popular method of processing (Singh and Saini, 2012) [47].

Higher energy density, vitamin content and improved digestibility of nutrients are some common features which can be achieved through malting (Preetika, *et al*., 2004) [50]. During germination process, starch is broken down into low molecular weight carbohydrates (oligoand disaccharide) by the activity of amylase enzymes. Resulted germinated flour had reduced water holding capacity and high energy density which enhance its potential in the production of infant foods, weaning foods and enteral foods. Malted millet flour can also be used in the production of various other items such as milk-based beverages, confectionary and cakes (Shobana *et al*., 2013) [48]. Germination process was found to be responsible for activation of enzymatic activity of sprouted seeds, thereby causing the disintegration of carbohydrates, proteins and lipids into simpler forms. Bioavailability of nutrients also improved significantly as a result of degradation of proteins by protease enzymes (Singh *et al*., 2015) [46].

Effect of germination on nutrient and anti-nutritional components was studied by various researchers as shown in Table I. Khetarpaul and Chauhan (1990) [19] reported that total soluble sugars (6.13 g/100 g), reducing (3.43 g/100 g) and non-reducing sugar (2.70 g/100 g) contents of germinated pearl millet were higher than the control sample values (1.76, 0.36, 1.40 g/100 g). Germinated slurry when processed by homogenization and autoclaving showed further enhancement of these components along with decreased starch content which might be due to starch hydrolysis accompanied by emission of greater soluble sugars content.

**References**


1. Abdelrahman A, Hoseney RC, Varriano-Marston E. Milling process to producelow-fat grits from pearl millet, Cereal Chemistry. 1983;60(3):189-191.
2. Adebiyi JA, Obadina AO, Adebo OA, Kayitesi E. Comparison of nutritional quality and sensory acceptability of biscuits obtained from native, fermented, and malted pear millet (*Pennisetum glaucum*) flour, Food Chemistry. 2017;232:210-217.
3. Agu HO, Jideani IA, Yusuf IZ. Nutrient and sensory properties of dambu produced from different cereal grains, Nutrition & Food Science. 2007;37(4):272-281
4. Balasubramanian S. A machine for dehulling millets, The Hindu, 2015, 2-3p.
5. Basavaraj G, Rao PP, Bhagavatula S, Ahmed W. Availability and utilization of pearl millet in India, SAT eJournal. 2010;8(1-6).
6. Bhati D, Bhatnagar V, Acharya V. Effect of pre-milling processing techniques on pearl millet grains with special reference to in-vitro iron availability, Asian Journal of Dairyand Food Research. 2016;35(1):76-80.
7. Chavan UD, Chavan JK, Kadam SS. Effect of fermentation on soluble proteins and *in vitro* protein digestibility of sorghum, green gram and gram blends, Journal of Food Science. 1988;53(5):1574-1575.
8. Chitra U, Singh U, Rao PV. Phytic acid, *in vitro* protein digestibility, dietary fiber and minerals of pulses as influenced by processing methods, Plant Foods for Human Nutrition. 1996;49(4):307-316.
9. Chowdhury S, Punia D. Nutrient and antinutrient composition of pearl millet grains as affected by milling and baking, Food/Nahrung. 1997;41(2):105-107.
10. Devisetti R, Yadahally SN, Bhattacharya S. "Nutrients and antinutrients in foxtail and proso millet milled fractions: evaluation of their flour functionality", LWT-Food Science and Technology. 2014;59(2):889-895.
11. Dhankher N, Chauhan BM. Effect of temperature and fermentation time on phyticacid and polyphenol content of rabadi – a fermented pearl millet food, Journal of Food Science. 1987;52(3):828-829.
12. Dharmaraj U, Ravi R, Malleshi NG. Cooking characteristics and sensory qualities of decorticated finger millet (*Eleusine coracana*), Journal of Culinary Science & Technology. 2014;12(3):215-228.
13. El Hag ME, El-Tinay AH, Yousif NE. Effect of fermentation and dehulling on starch, total polyphenols, phytic acid content and *in vitro* protein digestibility of pearl millet, Food Chemistry. 2002;77(2):193-196.
14. Elyas SH, El-Tinay AH, Yousif NE, Elsheikh EA. Effect of natural fermentation on nutritive value and *in vitro* protein digestibility of pearl millet, Food Chemistry. 2002;78(1):75-79.
15. Gabrelibanos M, Tesfay D, Raghavendra Y, Sintayeyu B. Nutritional and health implication of legumes, International Journal of Pharmaceutical Science and Research. 2013;4(4):1269-1279.
16. Galliard T. Rancidity in cereal products," in Allen, J.C. and Hamilton, R.J. (Eds), Rancidity in Foods, Aspen Publishers, Gaithersburg, 1999, 140-156p.
17. Hama F, Icard-Vernière C, Guyot JP, Picq C, Diawara B, Mouquet-Rivier C. Changes in micro and macronutrient composition of pearl millet and white sorghum during in field versus laboratory decortication, Journal of Cereal Science. 2011;54(3):425-433.
18. Hassan AB, Ahmed IAM, Osman NM, Eltayeb MM, Osman GA, Babiker EE. Effect of processing treatments followed by fermentation on protein content and digestibility of pearl millet (*Pennisetum typhoideum*) cultivars, Pakistan Journal of Nutrition, 2006, 5(1).
19. Khetarpaul N, Chauhan BM. Effect of fermentation on protein, fat, minerals and thiamine content of pearl millet", Plant Foods for Human Nutrition. 1989;39(2):169-177.
20. Khetarpaul N, Chauhan BM. Effect of germination and fermentation on available carhohydrate content of pearl millet, Food Chemistry. 1990;38(1):21-26.
21. Kindiki MM, Onyango A, Kyalo F. Effect of processing on nutritional and sensory quality of pearl millet flour", Food Science and Quality Management. 2015;42:13-19.
22. Legesse E. Effect of processing on qualtiy characteristics of pearl millet (*Pennisetum glaucum*) based value added

products, MSc thesis, 2013.
23. Lestienne I, Buisson M, Lullien-Pellerin V, Picq C, Trèche S. Losses of nutrients and anti-nutritional factors during abrasive decortication of two pearl millet cultivars (*Pennisetum glaucum*), Food Chemistry. 2007;100(4):1316-1323.
24. Mahajan S, Chauhan BM. Phytic acid and extractable phosphorus of pearl millet flour as affected by natural lactic acid fermentation, Journal of the Science of Food and Agriculture. 1987;41(4):381-38
25. Varriano-Marston E, Hoseney RC. Note on mineral content and location in pearl millet. Cereal Chemistry. 1980;68:437439.
26. Lai CC, Varriano-Marston E. Lipid content and fatty acid composition of free and bound lipids in pearl millet. Cereal Chemistry. 1980;57:271-274.
27. Taylor JRN. Millet: Pearl, In: Encyclopedia of grain science 2, ed. by Wrigley, C. Corke, H. and Walker, C.E., Elsevier, London, 2004, 253-261.
28. Taylor JR, Duodu KG. Effects of processing sorghum and millets on their phenolic phytochemicals and the implications of this to the health-enhancing properties of sorghum and millet food and beverage products, Journal of the Science of Food and Agriculture. 2014;95(2)25-237.
29. Jaybhaye1 RV, Pardeshi2 IL, Vengaiah3 PC, Srivastav PP. Journal Of Ready To Eat Food. Food Engg. Department, IIT Kharagpur, 2014, 1.
30. Ramaswami B, Pray CE, Kelley T. The impact of economic reforms on R&D by the Indian seed industry. Food Policy. 2001;26(6):587-598.
31. Pray CE, Ramaswami B, Timothy Kelley. The impact of economic reforms on R&D by the Indian seed industry. Food Policy 2001;26(6):587-598.
32. Carl E Pray, Sharmila Ribeiro, Rolf AE Mueller, P Parthasarathy Rao. Private research and public benefit: The private seed industry for sorghum and pearl millet in India. 1991;20(4):0-324. DOI:10.1016/0048-7333(91)90092-5
33. Sangeeta C Sindhu, Neelam Khetarpaul. Probiotic Fermentation of Indigenous Food Mixture: Effect on Antinutrients and Digestibility of Starch and Protein. 2001;14(6)601-609. DOI:10.1006/jfca.2001.1022
34. Fukushima M, Nakano M. E!ects of a mixture of organisms, actobacillus acidophilus or Streptococcus faecalis on cholesterol metabolism in rats fed on a fat and cholesterol enriched diet. Br. J Nutr. 1996;76(6):857-867.
35. Goldin BR, Gorbach SL. The effect of oral administration on *Lactobacillus* and antibiotics on intestinal bacterial activity and chemical induction of large bowel tumors. Developments in Industrial Microbiology. 1984;25:139-150.
36. Martınez-Villaluenga C, Gomez R. Characterization of bifidobacteria as starters in fermented milk containing raffinose family of oligosaccharides from lupin as perbiootic. International Dairy Journal. 2007;17:116-122.
37. Roberfroid M, Rowland I. Functional food science and gastrointestinal physiology and function. British Journal of Nutrition. 1998;80:147-171.
38. Simwemba CG, Hoseney RC, Varriano Marston E, Zeleznak K. Certain B vitamin and phytic acid contents of pearl millet [Pennisetum americanum (L.) Leeke]. Journal of Agricultural and Food Chemistry. 1984;32:31-37.
39. Raboy V. Seeds for a better future: Low phytate grains help to overcome malnutrition and reduce pollution. Trends in Plant Science. 2001;6:458-462.
40. Arora S, Jood S, Khetarpaul N. Effect of germination and probiotic fermentation on nutrient profile of pearl millet based food blends, British Food Journal 2011;113(4):470-481.
41. Ayo JA, Olawale O. Effect of defatted groundnut concentrate on the physico-chemical and sensory quality of fura, Nutrition & Food Science. 2003;33(4):173-176.
42. Jaybhaye RV, Pardeshi IL, Vengaiah PC, Srivastav PP. Processing and technology for millet based food products: a review, Journal of Ready to Eat Food. 2014;1(2):32-48.
43. Rai KN, Gowda CLL, Reddy BVS, Sehgal S. Adaptation and potential uses of sorghum and pearl millet in alternative and health foods, Comprehensive Reviews in Food Science and Food Safety. 2008;7(4):340-352.
44. Serna-Saldivar SO, Clegg C, Rooney LW. Effects of parboiling and decortication on the nutritional value of sorghum (sorghum bicolor L. Moench) and pearl millet (*Pennisetum glaucum* L.), Journal of Cereal Science. 1994;19(1):83-89
45. Singh P, Raghuvanshi RS. Finger millet for food and nutritional security, African Journal of Food Science, 2012;6(4):77-84.
46. Singh AK, Rehal J, Kaur A, Jyot G. Enhancement of attributes of cereals by germination and fermentation: a review, Critical Reviews in Food Science and Nutrition. 2015;55(11):1575-1589.
47. Singh NB, Saini RS. Products, diversification, marketing and price discovery of pearl millet in India, Documentation, National Rainfed Area Authority, Todapur Village, Pusa, 2012.
48. Shobana S, Krishnaswamy K, Sudha V, Malleshi NG, Anjana RM, Palaniappan L, et al. Finger millet (*Ragi*, *Eleusine coracana* L.): a review of its nutritional properties, processing, and plausible health benefits, Advances in Food and Nutrition Research. 2013;69:1-39.
49. Saleh ASM, Zhang Q, Chen J, Shen Q. Millet grains: nutritional quality, processing, and potential health benefits, Comprehensive Reviews in Food Science and Food Safety. 2013;12(3)281-295.
50. Preetika A, Padmini G, Shobha U. Nutrient dense mixes for enteral feeding in India, Nutrition & Food Science. 2004;34(6):277-281.
51. Coulibaly Abdoulaye, Brou Kouakou, Jie Chen. Phytic acid in cereal grains: structure healthy and harmful ays to reduce phytic acid in cereal and grains and their effects on nutritional quality.journal of plant nutritional and fertilization technology. 2011;1(1):1-22.
52. Cisse D, Guiro AT. Effect of food processing on iron availability of African pearl millet weaningf food. International journal of food science. 1998;49(5):375-381.
53. Malleshi NG, Desikaichar HS, Nutritive value of malted millet flour, Plant food for human nutrition. 1986;36(3):191-196.