REVIEW ARTICLE Agricultural Reviews, Volume 42 Issue 2 : 240-244 (June 2021)

Pearl Millet as a Sustainable Alternative Cereal for Novel Value-added Products in Sub-Saharan Africa: A Review

M. Dube[1,2], N. Nyoni[1], S. Bhebhe[1], M. Maphosa[1], A. Bombom[3]

10.18805/ag.R-174

ABSTRACT

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is an underutilized small grain, nutrient-rich cereal crop cultivated in the arid and semi-arid tropics of Asia and Africa. However, several barriers exist that preclude the full exploitation of the crop such as low yield, inadequate processing technologies, lack of extension support and limited productive varieties. Furthermore, anti-nutritional factors in the grain such as polyphenols reduce digestibility, palatability and bio-availability of other nutrients. Reduction or elimination of these anti-nutritional factors through pre-treatments like boiling, cooking, roasting, soaking improves the nutritional quality of the grain. Underutilized pearl millet genetic resources and processing has the potential to contribute towards sustainable agriculture particularly in drought prone and marginal areas of Africa. This review focuses on nutritional value, pearl millet cultivation and utilization challenges, processing and value addition interventions to improve crop adoption and productivity in sub-Saharan Africa.

Key words: Orphan crop, *Pennisetum glaucum*, Small grain.

Pearl millet [*Pennisetum glaucum* L. R. Br.] is a widely cultivated crop grown mainly for its grain and fodder. It is projected that by 2050, a 70-100% increase in cereal food supply will be required to feed the predicted world population growth of 9.8 billion people (Wang *et al.*, 2018). Accordingly, more needs to be done by developing countries particularly in sub-Saharan Africa (SSA) to ensure crop productivity and food security for this projected population growth. A boost in pearl millet is an alternative solution to this increasing food and nutritional demands (Serba *et al*., 2017). Pearl millet is a hardy crop with a relatively short growth period compared to maize (*Zea mays* L.*),* wheat (*Triticum aestivum*) and rice (*Oryza sativa* L.) that are widely grown in Africa. It can be grown in regions characterized by persistent low rainfall due to its ability to tolerate and survive under variable drought weather conditions associated with increased temperatures and high soil salinity (Varshney *et al*., 2017). Pearl millet performs relatively well in low-fertile soils and with lower inputs of water and fertilizers in semi-arid regions (Jiri *et al.,* 2017; Embashu and Nantanga, 2019). This cereal crop has the potential and desirable attributes to adapt to the harsh conditions when compared to other major crops (*e.g*., wheat, paddy and maize).

Being a C_4 plant, pearl millet has a higher water use efficiency compared to maize and sorghum that are widely grown in SSA (Singh *et al*., 2012). This characteristic makes pearl millet a relevant crop to water scarce situation in the semi-arid regions. Moreover, pearl millet germplasm is genetically diverse with great plasticity to adapt to erratic environments (Tadele, 2018). The crop is heat and drought tolerant with several genotypes reported to survive at temperatures as high as 62°C. Furthermore, the crop is the second most saline tolerant crop to barley which is a positive attribute in marginal and reclaimed areas. Developmental plasticity through primary and secondary tillering allows pearl millet to compensate for any crop failures (Tadele *et al.,* 2018). Lateral root system is a distinct feature in pearl millet that can penetrate soils rapidly (Tito *et al.*, 2018). Pearl millet tolerates water logging from poorly drained soils unsuitable for maize and wheat cereals (Singh *et al.,* 2012). Accordingly, these characters make pearl millet an ideal crop of choice in resource constrained environments where other crops may not be productive.

Pearl millet nutritional profile and health benefit

Pearl millet nutritional superiority is from elevated levels of protein, vitamins, essential amino acids, antioxidants and essential micronutrients (Saleh *et al.,* 2013). This is coupled with a comparatively large germ proportion than cereals such as sorghum which contributes to its higher nutritive value

[1]Department of Crop and Soil Sciences, Lupane State University, Box 70, Lupane, Zimbabwe.
[2]Department of Research and Specialist Services, Crop Breeding Institute, PBK 5137, Bulawayo, Zimbabwe.
[3]National Livestock Resources Research Institute (NaLIRRI), P.O. Box 5704, Wakiso, Uganda.

Corresponding Author: M. Maphosa, Department of Crop and Soil Sciences, Lupane State University, Box 70, Lupane, Zimbabwe. Email: mmaphosa@lsu.ac.zw

How to cite this article: Dube, M., Nyoni, N., Bhebhe, S., Maphosa, M. and Bombom, A. (2021). Pearl Millet as a Sustainable Alternative Cereal for Novel Value-added Products in Sub-Saharan Africa: A Review. Agricultural Reviews. 42(2): 240-244. DOI: 10.18805/ag.R-174.

Submitted: 16-09-2020 **Accepted:** 05-01-2021 **Online:** 02-03-2021

(Satankar *et al*., 2020). The essential amino acids include higher content of leucine, isoleucine and lysine comparable to wheat and rye (Hulse *et al.,* 1980; Rana and Dahiya, 2019). Furthermore, the crop is gluten-free, high in calcium, iron, zinc, vitamin A, riboflavin compared to other cereals (Table 1). Accordingly, incorporating millet into diets can be a sustainable way to curb nutrition related disorders (Datir *et al*., 2018).

Polyphenolic compounds, tannin, phytic acid, goitrogens and oxalic acid are some anti-nutritional components found in pearl millet grain (Ndiaye, 2018; Embashu and Nantanga, 2019). The crop bran specifically contains high concentration of polyphenols and tannin compounds. The concentration of these anti-nutritional attributes contributes towards protein indigestion (Gopalan *et al.,* 2016).

Pearl millet is considered a healthy cereal food crop due to low gluten proportions in the grain (Dudeja and Singh, 2017). In wheat and other cereal grains gluten causes celiac diseases and allergies (Gopalan *et al.,* 1987). Pearl millet has a potential to prevent cancerous effects due to proliferative properties associated with the presence of phenolic extracts (Upadhyaya and Vetriventhan, 2018). It is an anti-diabetic cereal grain crop compared to rice, wheat and sorghum (Krishnan and Meera, 2018). This is due to its low glycemic index and slow digestive ability caused by its raised fibre content (Jiri *et al.*, 2017).

African challenges in pearl millet cultivation and utilization

Despite the numerous benefits that pearl millet has to offer, SSA has not ripped maximum benefits from the crop. The major production constraints emanate from unreliable rainfall, poor crop management and limited extension education. Currently, crop yields range between 500 and 1500 kg/ha, but can further decrease to 150 kg/ha due to poor farming systems. During the growing season quelea birds are difficult to manage without additional labour to scare them. Inadequate processing technologies in pearl millet to address niche markets demands has a limiting effect in the crop utilization for its biobased products. Furthermore, at household level food product preparation from pearl millet is cumbersome. Post-harvest processing practices with no low-cost technologies such as threshers makes farmers shun the crop. These barriers to the wider use of this neglected poor man's crops expose the region into food insecurity and malnutrition. In most SSA countries, agricultural research, education and extension in agriculture have failed to collaborate to support and promote pearl millet productivity. Success in genetic enhancements of pearl millet which depends on the availability of genetic resources which is also a major constraint (Serba and Yadav, 2016) to enhancing productivity in Africa.

Pearl millet processing methods and end use

Knowledge and availability of pearl millet post-harvest processing technologies is limited in Africa. The products from the crop are primarily porridges and fermented beverages. Yet pearl millet can be processed into flour, roasted, popped, sprouted, salted into ready-to-eat grains for thick and thin porridges and confectionery. Processing pearl millet improves taste, nutritional value and overall product range (Singh *et al*., 2017; Ramashia *et al.,*2019).

Table 1: Pearl millet nutritive value compared to major cereal crops /100g edible portion, 12% moisture.

Constituent	Pearl millet	Sorghum	Maize	Finger millet	Wheat	Rice
Protein (g)	11.6	10.4	4.7	7.7	11.8	6.8
Fat (g)	5.0	1.9	0.9	1.5	1.5	0.5
Crude fibre (g)	1.2	1.6	1.9	3.6	1.2	0.2
Carbohydrates (g)	67.5	72.6	24.6	72.6	71.2	78.2
Minerals (mg)	2.3	1.6	0.8	2.7	1.5	0.6
Calcium (mg)	42	25	9	35	41	10
Phosphorous (mg)	296	222	121	350	306	160
Iron (mg)	8	4.1	1.1	3.9	5.3	0.7
Zinc (mg)	3.1	1.6	0	2.3	2.7	1.4
Sodium (mg)	10.9	7.3	51.7	49.0	17.1	0
Magnesium (mg)	137	171	40	78-201	138	90
Vitamin A (mg)	132	47	32		64	0
Thiamine (mg)	0.33	0.37	0.11	0.42	0.45	0.06
Riboflavin (mg)	0.25	0.13	0.17	0.19	0.17	0.06
Niacin (mg)	2.3	3.1	0.6	1.1	5.5	1.9
Folic Acid (mg)	45.5	20	0	0	36.6	8
Vitamin C (mg)	0	0	0	0	0	6

Source: Saleh *et al.,* 2013 Gopalan *et al.,*2016; Hulse *et al.,*1980.

Furthermore, processing reduces anti-nutritional factors and enhances bioavailability and digestibility of more nutrients. Caution needs to be exercised when processing using other methods since they reduce shelf-life of pearl millet due to its high fat content. In this section focus is on low-cost technologies that households can undertake to improve food security and nourishment.

Dehulling

This is the removal of the outer layer of the grain (hull and pericarp) by hand pounding, abrasive mill or disks with mechanical dehullers (Rani *et al.*, 2018). For long term storage of pearl millet kernels can be kept intact and only dehulled for immediate use.

Milling

The processing method is meant for the production of fine flour which is done by reducing the size the grain by crushing. Pearl millet can be milled using a hammer and roller mill producing flour for porridge, baked and steamed food products. However, this process reduces the shelf-life of the flour due to oxidation of released fatty acids (Santakar *et al*., 2020). The greatest benefit of milling is the reduction of antioxidants in the bran (Sridevi *et al*., 2010).

Malting

Malting is germination of grain under controlled conditions which breaks down starch to simpler sugars (Suma and Urooj, 2017). Furthermore, vitamin content, protein quality and digestibility are enhanced after pearl millet grain malting. Flour from germinated grain has reduced water holding capacity and high energy density which enhances its potential to produce infant foods, weaning foods and enteral foods. Malted pearl millet flour can produce milk-based beverages, confectionary and cakes (Dias-Martins *et al.,* 2018).

Fermentation

This is achieved through malting and souring with mixed cultures of yeast and Lactobacilli (Dias-Martins *et al*., 2018). Pearl millet starch and soluble sugars are degraded from the grain and fermenting media by enzymes. The benefit of fermentation is the reduction of phytic acid and increase in phosphorus content (Wang *et al.,* 2018). Non-alcoholic beverages such as *ontaku*, *mahewu, obushera* widely brewed in several African countries can diversify the product portfolio of pearl millet (Embashu and Nantanga, 2019; Santakar *et al*., 2020).

Blanching

This enhances the shelf life of pearl millet flour through enzyme activity reduction without compromising nutritional value (Rani *et al.,* 2018). Blanching is achieved through sub-merging the pearl millet grain in hot water for a specified short period and drying (Dias-Martins *et al.,* 2018). High blanching temperatures reduces fat acidity, acid value and percentage free fatty acid profile levels in a pearl millet meal. Polyphenols and phytic acid contents are reduced when the pearl millet grain is exposed to dry heat treatment above 90^{o}C (Ndiaye, 2018). Furthermore, increased heat treatment slows the lipase activity and reduces decomposition of the lipids at storage.

Acid treatment

This treatment technique involves soaking grain in an acid such as hydrochloric acid. Use of acid treatment is important in the production of pearl millet food products that have low anti-nutritional content; high mineral bioavailability and better coloration. Lighter colour enhances food utilization and acceptance (Suma and Urooj, 2017).

Heat treatment

Better keeping quality in pearl millet flour emanates from dry heat treatment of grain prior to milling which limits lipase activity (Vinoth and Ravindhran, 2017). Dry heat reduces fat acidity, free fatty acid and lipase activity of pearl millet flour which causes bitterness and odour (Dias-Martins *et al.,* 2018).

Opportunities and proposed direction for developing countries

Pearl millet has a potential to be utilized as a grain and fodder crop to support integrated crop-livestock systems that typify most of SSA. The large genetic variability in the germplasm can support and supply several quality traits (Gwamba *et al.*, 2019). Biobased food products and downstream commercial industries can be developed from the crop through improved crop adoption systems. Reduction in the production cost from these novel value-added products and supportive government policies are the prerequisites for commercialization of pearl millet crop. Farmer centric approaches through research, education and extension interaction will help improve and disseminate pearl millet production technologies that will help and upgrade the farming systems resulting in improved yields per unit area cultivated. In future breeding pearl millet varieties for increased grain yield without regard to quality will be a major mistake that will affect the crop acceptance in the production chain. Ultimately, Consultative Group for International Agricultural Research (CGIAR**)** and the National Agricultural Research System (NARS) should not only focus entirely on pearl millet grain yield and include specialty types. This continued, focused, fundamental and applied research will stimulate demand by various stakeholders in the pearl millet production cycle. Promotional campaigns to increase public awareness of alternative products from pearl millet and available processing techniques for the diverse pearl millet germplasm should be launched. Furthermore, smallholder farmers should participate in value chain activities to empower them with reliable and quality planting material, production skills and link them to profitable market.

Conclusion

Pearl millet has the potential to contribute globally towards adequate food security and alleviate malnutrition challenges. It is a suitable alternative crop to mitigate the effects of climate change to maintain food security in Africa. High priority should be on the genetic improvement of pearl millet genotypes and their utilization for commercial exploitation and use as feed and food crops.

Acknowledgement

The work described in this paper was carried out with the financial support of the Benefit-Sharing Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture (Reference Number LoA/TF/PR-316-Uganda/2019/CBDT).

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