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Review Article

Improving the Nutritional and Functional Properties of Pearl Millet Pasta: A Review

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ABSTRACT

Pasta, generally prepared from durum wheat is extensively consumed worldwide. Apart from being healthy and convenient food, the other outstanding characteristics of pasta include, low glycemic index, low cost, ease of preparation, extended stability during storage with relatively easier preparation. For functional pasta, care must be given to ensure that the added ingredient should enhance the nutritional profile, have minimal impact on pasta quality, palatability and consumer preferences. This review paper presents an overview of the various processing aspects of pearl millet. This comprises recent information about the improvement in the storage period of pearl millet flour (PMF), development of pearl millet pasta and addition of functional ingredients to enhance its nutritional quality. It is observed that the keeping quality of PMF can be enhanced by adopting germination, roasting, fermentation, microwave treatment, hydrothermal treatment, and refrigeration. Development of complete pearl millet pasta is not possible; functional pearl millet-based pasta can be designed using composite flour, the addition of pulses, legumes, fruit and vegetable powder to increase the demand for pearl millet.

RESEARCH ARTICLE

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- Anatomy,
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INTRODUCTION

Pasta is popular ready to cook cereal food among young as well as old generation across the world. In recent times, the popularity of pasta has amplified drastically, with higher than 30 different brands in the Indian market having worth of around 250-300 crore (Anonymous, 2016a; Anonymous, 2016b). The global pasta market was having a worth of 22.3 billion US$ in 2021 with major dominance from the European companies. The market of North America, Asia Pacific, Europe, Latin America, Middle East and Africa are also having significant market share. Pasta products from companies like Barilla Holding, Grupo Ebro Puleva, Nestle, De Cecco, Makfa, etc. are more prevalent and preferred by the consumers (Anonymous, 2021). Conventionally, pasta products are prepared using an appropriate and homogeneous blend of durum wheat semolina and water. This mixture in dough form is subjected to extrusion to attain a required shape at ambient temperature and pressure or sometimes under vacuum followed by drying (Aktan and Khan, 1992). It has been reported that few human beings cannot tolerate wheat gluten, which is associated with celiac disease, wheat allergy, and non-celiac gluten sensitivity a specific disorder of intestinal absorption (Kowlessar, 1972). As per the reports, about 6-8 million people in India are affected from the celiac disease (Anonymous, 2017).

The primary purpose for cultivating pearl millet is for its utilization as food and forage in the semi-arid tropics and drought-prone regions of Asia and Africa (Satyavathi *et al.*, 2021). On the contrary, it is being used as a feed for poultry and livestock in USA (Serba *et al.*, 2020). The incorporation of pearl millet flour for preparing pasta-like products would be beneficial, owing to its in carbohydrate (67.5 g per 100 g), fat (5 g per 100 g), protein (11.6 g per 100 g), fiber (1.2 g per 100 g), mineral (2.3 g per 100 g), iron (8 mg per 100 g), calcium (42 mg per 100 g), zinc (3.1 g per 100 g) and vitamin B, especially niacin, B6 and folic acid. Pearl millet is a gluten-free grain having abundant energy, i.e. 361 kcal per 100 g, which is comparatively higher than rice (345 kcal per 100 g), wheat (346 kcal per 100 g), sorghum (349 kcal per 100 g) and maize (125 kcal per 100 g) (Gopalan *et al.*, 2004; Leder, 2004). Consequent to cooking, pearl millet can retain its alkaline properties, making it suitable people with wheat allergies (Satyavathi *et al.*, 2021).

Pearl millet contains phytic acid, trypsin inhibitors, tannins, goitrogens and oxalic acid, which act as antinutritional factors and hence reduce the bioavailability of the nutrients present in the grain. Bitterness and rancidity become crucial for maintaining the pearl millet flour (PMF) quality while storage at moist conditions and with higher exposure of oxygen (Nantanga *et al.*, 2008). Hence, the processing of pearl millet demands the inactivation of antinutritional factors to avail full benefits of its nutritional qualities.

Owing to the increasing awareness about having a healthy lifestyle, many people are preferring high fiber and low-fat foods in their diet. Many nutritive and fortified products from pasta are emerging with added proteins, minerals, vitamins from pulses, legumes and soybean etc. Therefore, the development and adoption of pearl millet-based pasta with functional ingredients provides a great opportunity for value addition and improving the nutritional status of the consumers. Hence, this review papaer was intended to systematically compile and review the nutritional properties of pearl millet, milling and storage of PMF, the addition of functional constituents and storage conditions on the quality aspects of pearl millet pasta.

ANATOMY AND NUTRITIONAL PROPERTIES

The structure of pearl millet grain is shown in Figure 1. The pericarp is composed of epicarp, mesocarp and endocarp. The seed coat present below the endocarp has 0.4 µm of thickness. The aleurone layer is underneath the seed coat having a thickness of one cell layer. Starchy endosperm is composed of peripheral, corneous and floury areas. The aleurone, pericarp and endosperm portions of pearl millet have the presence of polyphenolic pigments. The taste and the grain's unattractive grey colour are takes place due to these pigments (McDonough and Rooney, 1989).

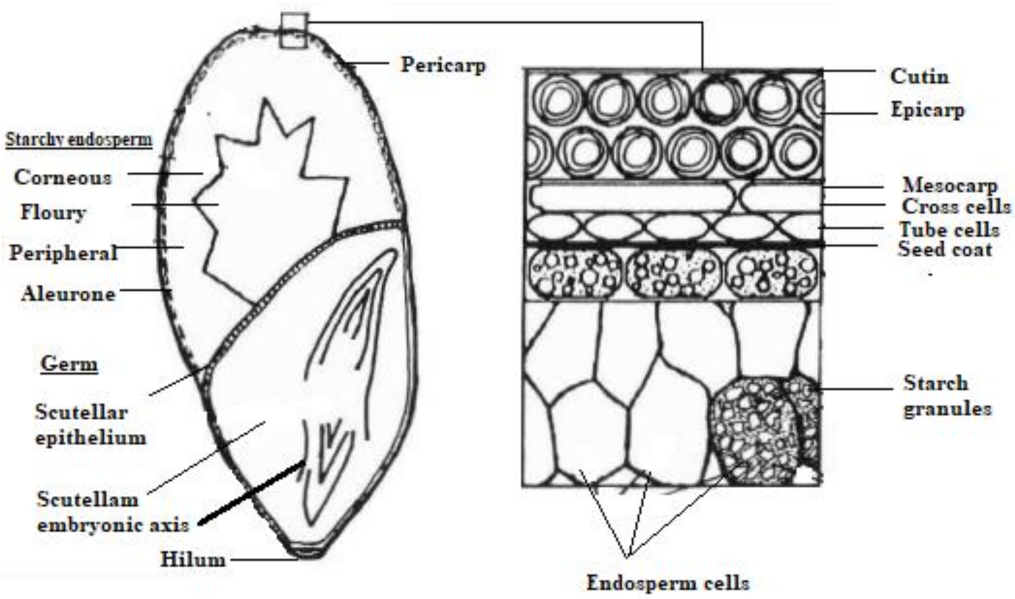

Figure 1. Overall structure of pearl millet grain (McDonough and Rooney, 1989).

The presence of germ percentage in pearl millet grain is more than other cereal grains except maize (Abdelrahman *et al.*, 1984). Pearl millet grains were found in three different sizes such as large size kernel (>2920 µm), medium-size kernel (<2920 but >2240 µm), and small size kernel (<2240 µm). Reduction in the seed size is related to the increased percentage of bran and decrease in the proportion of endosperm (Table 1).

The protein content (%) in whole grain, endosperm, germ and bran was reported to be 13.27, 10.88, 24.52 and 17.07, respectively. The corresponding fat content in whole grain (6.26%), endosperm (0.53%), germ (32.18%) and bran (5.04%), whereas the ash percentage were whole grain (1.68%), endosperm (0.32%), germ (7.18%) and bran (3.20%), respectively (Abdelrahman *et al.*, 1984).

Table 1. Proportions of different parts of pearl millet.

Size	Weight (mg)	Endosperm (%)	Germ (%)	Bran (%)
Large	18.94	76.21	16.62	7.17
Medium	13.74	75.08	17.40	7.52
Small	10.39	73.89	15.47	10.64

McDonough and Rooney (1989) reported that pearl millet exhibited different shapes (obovate, lanceolate, hexagonal and globose) (Figure 2) and colour (white, yellow, brown, purple and grey).

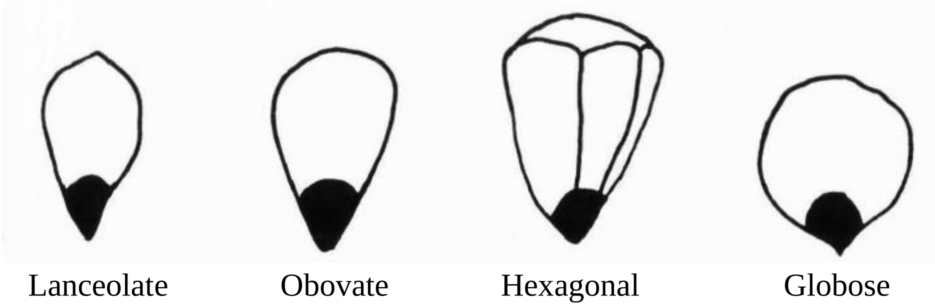

Figure 2. Shapes of pearl millet grain (McDonough and Rooney, 1989).

Tiwari *et al.* (2014) reported the composition of pearl millet including moisture (10.4%), protein (12.2%), ash (1.5%), crude fibre (1.74%), fat (1.5%), carbohydrate (70.34%), iron (6.86 mg per 100 g), zinc (3.059 mg per 100 g), antioxidant activity (0.353 mmolTrolox per g), phytic acid (728 mg per 100 g), total polyphenols (352.6 mg per 100 g) and tannin content (0.14% CE).

Jalgaonkar and Jha (2016) emphasized the significance of reduced particle diameter (780, 600, 500, 425, 313.5 and 241 µm), which has resulted in increasing the nutritional profile of PMF. Results indicated that reduction in the particle size from 241 to 780 µm has yielded variation in the protein (9.83-13.43%), fat (1.49-6.15%), ash (0.81-2.02%), iron (8.79-9.07 mg per 100 g), and zinc (2.72-3.13 mg per 100 g) content. This trend could be attributed to the size reduction of bran and aleurone layers into finer particles; however, the endosperm was pulverized into coarser particles.

Pre-treatment effect on the storage of PMF

PMF has a tendency to become bitter and rancid within a short storage period. The reason is the conversion of glycerides and following with the increase of free fatty acids owing to the presence of an active lipase enzyme in PMF (Pruthi 1981; Arora *et al.*, 2002).

Such undesirable chemical reactions are generally responsible for the development of off-flavour compounds predominantly under the presence of higher moisture and oxygen during storage (Nantanga *et al.*, 2008). Germination, roasting, fermentation, microwave treatment, hydrothermal treatment, and refrigeration are reported by researchers to enhance the keeping quality of PMF.

Effect of malting (16 h with germination of 48 or 72 h, followed by kilning for 24 h at 50°C), and hot water blanching (98°C for 30 s) on pearl millet was studied by Archana *et al.* (1998). Results indicated a significant decrease in grain's antinutritional factors (polyphenols and phytic acid) due to malting and blanching treatment. The decrease in polyphenols was 28%, 38% and 40% in blanching, malting 48 h and malting 72 h treatments, respectively. The corresponding value for phytic acid was 38%, 46% and 53%, respectively. Malting of pearl millet grain showed higher destruction of antinutritional factor. Among the three treatments, the malting of grain for 72 h was superior in minimizing the polyphenols and phytic acid. Similar findings were reported by Osman (2009) that germination of pearl millet grain for 5 days of pearl millet caused a reduction in phytic acid and protein digestibility. Also, germination treatments coupled with other indigenous treatments such as fermentation will reduce tannin content and improve the nutritional content.

Olamiti *et al.* (2020) concluded that malting (MT) was done by keeping the grains in distilled water for 6 h followed by washing with formaldehyde, germination for 24 h, 48 h, and 72 h at 25°C, drying at 50°C for 10 h and packing in airtight polyethylene resealable bags) and fermentation (FT) (using lactic acid bacteria for 24-72 h at 25°C followed by draining, washing and drying at 50°C for 10 h) treatment to two pearl millet cultivars had a prominence effect on crystallinity as well as functional groups of the treated flour. The optimal processing time for MT and FT of colour were reported as 54.40 and 63.30 h for Babala pearl millet cultivar (BPM) and 50.69 and 39.38 h for Agrigreen pearl millet cultivar (APM). The optimum time for MT and FT of thermal properties were 40.94 and 29.07 h for BPM, and 45.78 and 42.60 h for APM, respectively.

Arora *et al.* (2002) highlighted the effect of dry heat treatment (100 ± 2°C for 120 min) applied to pearl millet grains before milling has substantially improved the storage life of PMF without affecting its acceptability. The study corroborated that increasing fat acidity is among the promising indicators reflecting PMF deterioration during storage. Fat acidity values of the heat-treated flour raised from 30.3-123.7 mg KOH per 100 g and 28-50.5 mg KOH per 100 g, respectively, during storage study of 28 days.

Rathi *et al.* (2004) reported that inactivation of lipase activity by depigmentation method had improved the colour of pearl millet. The depigmentation method included dipping grain in 0.2 N HCL solution for 18 h and then blanching (98°C for 30 s). The method improved the colour of grain and sensory quality parameters, soluble dietary fibre, in-vitro protein digestibility, and in-vitro starch digestibility of pearl millet pasta by preserving the nutritional content. The flour prepared from lighter colour of grain was successfully utilized for the making pasta.

Nantanga *et al.* (2008) reported that toasting treatment (120°C for 16 h) was more efficient than boiling treatment (100°C for 15 min) to the pearl millet. The fat acidity observed of flour samples, i.e. untreated (0.11 to 3.73 g per kg), toasted (0.01 to 0.68 g per kg), and boiled (0.00 to 0.04 g per kg) increased during three months of storage.

Mohamed *et al.* (2011) reported storage of flour (whole and dehulled pearl millet flour) under refrigeration (4±1°C) condition had a non-significant effect on the increase in antinutritional parameters (polyphenols and phytic acid). However, refrigeration in combination with cooking treatment (20 min in water bath followed by drying, grinding and pass through 0.4 mm screen) and then storing for one and two months at ambient temperature (25°C) or refrigeration (4±1°C) controlled the increase in antinutritional factors during refrigerated storage.

Yadav *et al.* (2012a) highlighted that microwave treatment (900 W, 2450 MHz for 80 s) to pearl millet grain (18% moisture) was significantly reduced the lipase activity with the increase in storage quality of treated flour up to one month at room condition.

Yadav *et al.* (2012b) reported that hydrothermal treatment (steaming at 1.05 kg per m^2) before (20 min) and after (15 min) pearling ceased the lipase activity. Treated flour samples kept in polyethylene pouches (75 μ) were found in good condition for up to 50 days when stored at room condition (15-35°C).

Tiwari *et al.* (2014) reported that fermentation (36 h) and dry heat treatment (100°C for 60 s) to pearl millet grain caused a reduction in phytic acid (45.32% and 43.88%), total polyphenols (20.96% and 0.69%), iron (2.19% and 1.02%) and zinc content (8.14% and 2.42%), respectively. Percentage reduction in iron and zinc content was minimum in heat-treated grain compared to pearled (25 min) and fermented grain. The storage life of PMF at ambient conditions for pearled, fermented and heat- treated flour was 2, 4 and 6 days, respectively.

Jalgaonkar *et al.* (2016) found that untreated, roasted (110°C for 60 s), and hydrothermally treated (boiling water for 15 min, followed by drying at 60°C for 2 h) PMF can be stored up to 2, 2 and 30 days at ambient conditions and 3, 3 and 45 days, respectively, at controlled condition (30±1°C at 50±2% RH) without undue deterioration in quality.

Effect of functional ingredients on quality of the pasta

The presence of gluten protein in durum wheat (*Triticum durum*) semolina is associated with specific disorders like celiac disease, wheat allergy, and non-celiac gluten sensitivity. The inadequacy of micronutrients and excess of toxic ions are of concern for the consumption of wheat (Abecassis *et al.*, 2000). The usage of pearl millet having good sources of nutrients, especially micronutrient as well as gluten-free grain for preparation of pasta provides great opportunity for value-addition. Incorporating millet by 100% or substituting wheat to maximum percentage in pasta improves nutritional profile and makes them superior to wheat-based pasta.

Pearl millet grain possesses undesirable grey colour due to the presence of polyphenolic pigments, affecting its sensorial properties. Hence, to improve its colour and nutritional properties, Rathi *et al.* (2004) carried out depigmentation of pearl millet flour. The authors prepared pasta from raw and depigmented PMF along with chickpea flour (4:1) and reported that depigmentation significantly improved the pasta colour. The protein, dietary fibre, fat, ash percentage of raw and depigmented pearl millet pasta was higher than pasta from complete semolina. In vitro starch and protein, digestibilities improved significantly by 16.9% and 6.56%, respectively, after depigmentation. A decrease in protein and total dietary fibre content by 6.74 and 4.01% was observed in the pasta obtained from depigmented flour. The depigmentation of pearl millet was an effective technique for the development of pasta with better quality and digestibility.

Yadav *et al.* (2014) optimized the formulation of wheat: PMF (9:1) with different vegetable paste (2 % dry solids of tomato, carrot, spinach, turnip) for the development of vegetable blended composite pasta. Pasta prepared in this experiment had iron (2.7-4.3 mg per 100 g), calcium (23.5-40.9 mg per 100 g), phosphorous (121-244 mg per 100 g), sodium (8.9-21.1 mg per 100 g), and potassium

(130-190 mg per 100 g). The addition of vegetable paste resulted in an increase in the firmness, with minimum stickiness and grueling loss, shelf-life of 3 months without adding preservative was achieved. The consumers accepted the product in terms of colour, aroma, texture, taste, mouthfeel under ambient storage conditions.

Devi *et al.* (2015) utilized the cold extrusion technique and prepared gluten-free sweet vermicelli with different constituents *viz.* pearl millet (30%-80%), roasted green gram (20 %-23.5%), sorghum (15%-30%), guar gum (1%-2%), and sugar (12%-20%). The optimized composition adjudged was pearl millet (48%): sorghum (15%): green gram (23.5%): guar gum (1.5%): sugar (12%). The obtained vermicelli prepared was found to be superior based on the nutritional, sensorial characteristics along with the shelf life of 3 months.

Gull *et al.* (2015) used PMF (10-50 %), finger millet flour (FMF) (10-50 %), and carrot pomace powder (CPP) (2-10 %) as a substitution of semolina for pasta preparation. Cooking loss in durum wheat semolina pasta was found as 7.66% but gradually increased from 13.60 to 17.20 % and 15.20 to 24.40 % and 10 to 16.40% with an increased percentage of PMF (10-50%), FMF (10-50%) and CPP (2-10%), respectively. The control pasta showed the highest firmness (5.94 N) and cooked weight (33.93 g per 10 g), and consequent to the incorporation of CPP, FMF and PMF, the firmness and cooked weight decreased from 4.24 to 2.14 N, and 32.34 to 25.07 g per 10 g, respectively. The optimized incorporation of 4% CPP, 20% FMF and 30% PMF in durum wheat semolina was found better by keeping cooking weight, cooking loss, colour, and firmness of pasta in consideration.

Jalgaonkar and Jha (2016) determined the influence of particle size (241 to 780 μm) of PMF on the quality characteristics of pasta and mentioned 450 μm particle size as the best.

They emphasized that the development of pasta using 100% PMF irrespective of its particle size can't be achieved due to the drawbacks of retaining physical integrity/stability after cooking. The blend composition (wheat semolina: pearl millet) as 70:30 was better. The addition of pearl millet resulted in increased protein, zinc and iron content of pasta; however, the textural properties (hardness, gumminess, chewiness, and springiness) were decreased. The optimized blend composition had cooking losses (<8%), protein content (>10%), and ash content (<0.7%). It was also recommended that maximum PMF incorporation in the blend can be 50:50 for obtaining pasta with acceptable quality and enhanced nutritional benefits.

Pearl millet-based pasta was prepared and stored at ambient conditions for 6 months in 100 μm thick biaxially oriented polypropylene (BOPP) films. The analysis revealed proportionate increase in moisture content (from 8.87 to 11.90%), water activity (from 0.51 to 0.66), free fatty acid (from 0.48 to 0.82 %), peroxide value (from 2.10 to 5.79 meq per kg of oil), fat acidity (from 20.54 to 37.77 mg per 100 g) during the entire storage. However, no microbial growth (total plate count, yeast, mould, *E. Coli*, *Salmonella,* and *Shigella)*, as well as presence of rancidity or bitter taste as evaluated by sensory evaluation report was detected (Jalgaonkar *et al.*, 2017).

Jalgaonkar *et al.* (2017) developed functional pearl millet pasta by incorporating defatted soy flour (DSF), carrot powder, (CP) mango peel powder (MPP), and moringa leaves powder (MLP) (Fig. 3). The authors concluded that 15% DSF, 10% CP, 5% MPP, and 3% MLP can be incorporated for obtaining better pasta which was also suitable in terms of colour, cooking loss (<8%), hardness and sensory attributes. A percentage reduction of about 5-7% in the nutritional composition of functional pasta was observed while cooking.

Jalgaonkar *et al.* (2019) highlighted that optimum extrusion operating conditions for the development of pasta from pearl millet (wheat semolina: PMF as 50:50) was obtained at 70°C (barrel temperature), 30% (w.b.) (feed moisture content), 12 rpm (feeder speed) and 1:10 (screw speed: feeder speed) with lesser cooking time (≤ 5.25 min), cooking loss (≤ 7.45%) and high hydration capacity (≥ 2.30 g per g), SC (≥ 3.14 ml per g), good hardness (≥ 11.11 N), SP (≥ 1.24 N) and CH (≥ 6.09 N mm).

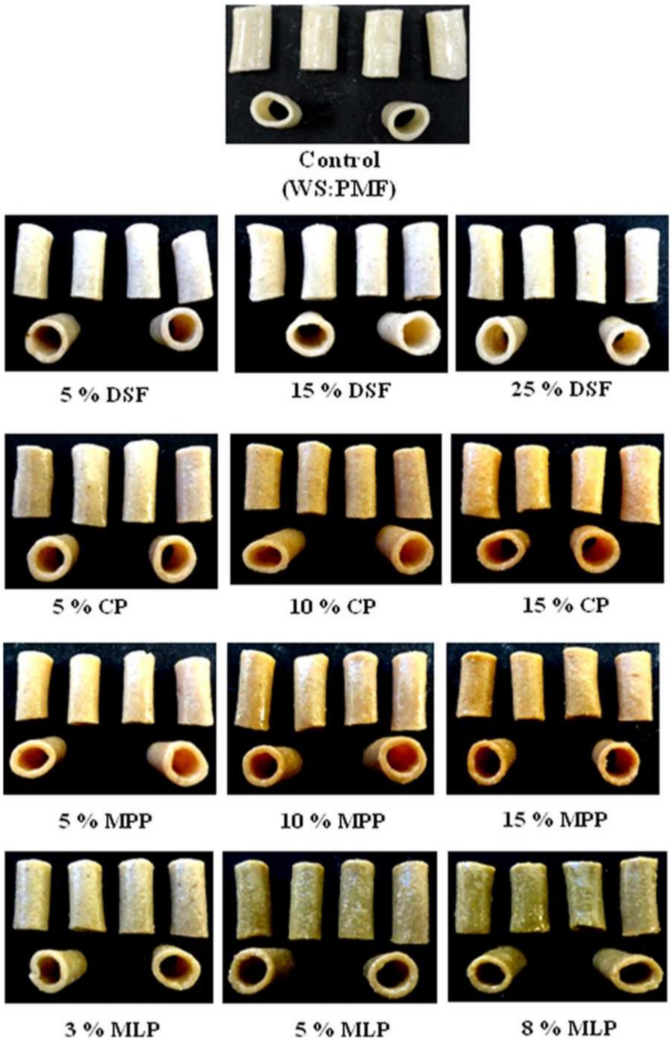

Figure 3. Cooked pearl millet-based pasta incorporated with different levels of DSF, CP, MPP, MLP (Jalgaonkar *et al.*, 2018).

CONCLUSION

The information presented in this review will encourage the overall utilization of pearl millet, highlighting its nutritional and therapeutic benefits. The development and adoption of pearl millet pasta with the incorporation of functional ingredients provide a great opportunity for value addition, thereby improving the nutritional status of the consumers with protection from degenerative diseases.

DECLARATION OF COMPETING INTEREST

The authors declare that they don't have any conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Kirti Jalgaonkar: Conceptualization, formal analysis, methodology, supervision, writing-original draft.
Manoj Kumar Mahawar: Supervision, validation, visualization, writing-review & editing.
Sharmila Patil: Conceptualization, methodology, supervision, writing-original draft
Jyoti Dhakane-Lad: Formal analysis, visualization, writing-review & editing.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

REFERENCES

Abdelrahman A, Hoseney RC and Varriano-Marston E (1984). The proportions and chemical compositions of hand-dissected anatomical parts of pearl millet. *Journal of Cereal Science*, *2(2): 127-133*.

Abecassis J, Autran JC and Feillet P (2000). Durum Wheat, Semolina and Pasta Quality: Recent Achievements and New Trends, Montpellier, France, pp. 42.

Aktan B and Khan K (1992). Effect of high-temperature drying of pasta on quality parameters and on solubility, gel electrophoresis, and reversed-phase high performance liquid chromatography of protein components. *Cereal Chemistry*, *69(3): 288-295*.

Anonymous (2016a). http://fmtmagazine.in/interview022014.html. (01 August 2016).

Anonymous (2016b). http://economictimes.indiatimes.com/industry/cons-products /fmcg/itc-market-share-in-instant-noodles-segment-rises-to-30-40/articleshow /51481603.cms. (01 August 2016).

Anonymous (2017). https://www.ndtv.com/food/6-to-8-million-indians-suffer-from-celiac-disease-go-gluten-free-to-manage-the-condition-1748085. (28 April 2022).

Anonymous (2021). https://www.imarcgroup.com/pasta-market. (27 April 2022).

Archana, Sehgal S and Kawatra A (1998). Reduction of polyphenol and phytic acid content of pearl millet grains by malting and blanching. *Plant Foods for Human Nutrition*, *53: 93-98*.

Arora P, Sehgal S and Kawatra A (2002). The role of dry heat treatment in improving the shelf life of pearl millet flour. *Nutrition and Health, 16: 331-336.*

Devi KP, Prema RS, Vaidheswaran H, Sudha A and Sangeetha V (2015). Quality evaluation of non wheat sweet vermicelli. *International Journal of Engineering and Techno Science, 1(1): 1-6.*

Gopalan C, Rama Sastri BV and Balasubramanian SC (2004). Nutritive value of Indian foods, second ed. National Institute of Nutrition, ICMR, Hyderabad, India, pp. 47.

Gull A, Prasad K and Kumar P (2015). Effect of millet flours and carrot pomace on cooking qualities, color and texture of developed pasta. *LWT- Food Science and Technology, 63: 470-474.*

Jalgaonkar K and Jha SK (2016). Influence of particle size and blend composition on quality of wheat semolina and pearl millet pasta. *Journal of Cereal Science, 71: 239-245.*

Jalgaonkar K, Jha SK and Mahawar MK (2018). Influence of incorporating defatted soy flour, carrot powder, mango peel powder and moringa leaves powder on quality characteristics of wheat semolina-pearl millet pasta. *Journal of Food Processing and Preservation, 42(4): e13575.*

Jalgaonkar K, Jha SK and Sharma DK (2016). Effect of thermal treatments on the storage life of pearl millet (Pennisetum glaucum) flour. *Indian Journal of Agricultural Sciences, 86(6): 762-767.*

Jalgaonkar K, Jha SK, Mahawar MK and Yadav DN (2019). Pearl millet based pasta: optimization of extrusion process through response surface methodology. *Journal of Food Science and Technology, 56(3):1134-1144.*

Jalgaonkar K, Jha SK, Nain L and Iquebal MA (2017). Quality Changes in Pearl Millet Based Pasta during Storage in Flexible Packaging. *Journal of Agricultural Engineering, 54(3): 22-31.*

Kowlessar OD (1972). Dietary gluten sensitivity updated. *Journal of the American Dietetic Association. 60(6): 475-477.*

Leder I (2004). Sorghum and Millets, in cultivated plants, primarily as food sources, [Ed. Gyorgy Fuleky], in Encyclopedia of Life Support Systems (EOLSS), Developed under the Auspices of the UNESCO, Eolss Publishers, Oxford, U.K.

McDonough CM and Rooney LW (1989). Structural characteristics of *Pennisetum americanum* (pearl millet) using scanning electron and florescence microscopy. *Food Microstructure, 8: 137-149.*

Mohamed EA, Ali NA, Ahmed SH, Mohamed Ahmed IA. and Babiker EE (2011). Effect of refrigeration process on antinutrients and HCL extractability of calcium, phosphorus and iron during processing and storage of two millet cultivars. *Innovative Romanian Food Biotechnology, 8: 13-21.*

Nantanga KKM, Seetharaman K, Kock HL and Taylor JRN (2008). Thermal treatments to partially pre-cook and improve the shelf life of whole pearl millet flour. *Journal of the Science of Food and Agriculture, 88: 1892-1899.*

Olamiti G, Takalani TK, Beswa D and Jideani AIO (2020). Effect of malting and fermentation on colour, thermal properties, functional groups and crystallinity level of flours from pearl millet *(Pennisetum glaucum*) and sorghum (*Sorghum bicolor*). *Heliyon, 6: e05467.*

Osman MA (2009). Effect of germination on the nutritional quality of pearl millet. *Journal of Agricultural Science and Technology, 3(8): 1-6.*

Pruthi TD (1981). Free fatty acid changes during storage of bajra (*Pennisetum typhoideum*) flour. *Journal of Food Science and Technology, 18(6): 257-258.*

Rathi A, Kawatra A and Sehgal S (2004). Influence of depigmentation of pearl millet (*Pennisetum glaucum* L.) on sensory attributes, nutrient composition, in vitro protein and starch digestibility of pasta. *Food Chemistry, 85: 275-280.*

Satyavathi CT, Ambawat S, Khandelwal V, and Srivastava RK (2021). Pearl millet: A climate-resilient nutricereal for mitigating hidden hunger and provide nutritional security. *Frontiers in Plant Science, 1828.*

Serba DD, Yadav RS, Varshney RK, Gupta SK, Mahalingam G, Srivastava RK...Tesso TT (2020). Genomic designing of pearl millet: a resilient crop for arid and semi-arid environments. *In Genomic Designing of Climate-Smart Cereal Crops, ed C. Kole (Springer Nature), 221–286.*

Tiwari A, Jha SK, Pal RK, Sethi S and Krishan L (2014). Effect of pre-milling treatments on storage stability of pearl millet flour. *Journal of Food Processing and Preservation, 38: 1215-1223.*

Yadav DN, Anand T, Kaur J and Singh AK (2012a). Improved storage stability of pearl millet flour through microwave treatment. *Agricultural Research, 1(4): 399-404.*

Yadav DN, Kaur J, Anand T and Singh AK (2012b). Storage stability and pasting properties of hydrothermally treated pearl millet flour. *International Journal of Food Science and Technology, 47(12): 2532-2537.*

Yadav DN, Sharma M, Chikara N, Anand T and Bansal S (2014). Quality characteristics of vegetable-blended wheat pearl millet composite pasta. *Agricultural Research, 3(3): 263-270.*