Quality evaluation of pearl millet based pasta as affected by depigmentation

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The effect of depigmentation on colour, nutritional, anti-nutritional, cooking and textural qualities of pasta prepared from pearl millet was studied. Depigmentation was achieved by soaking pearl millet grains in hydrochloric acid of 0.2 N for 18 h at 28–32°C fol1owed by washing, blanching (98°C for 30 sec) and tray drying (50°C). Pasta prepared from 100% wheat semolina (WS), 100% native pearl millet flour (PMF) and blend (50 : 50) of wheat semolina and native pearl millet flour (WS : PMF) were compared with pasta prepared from blend (50 : 50) of wheat semolina and depigmented pearl millet flour (WS : DPMF). It was observed that depigmentation significantly improved the colour of pasta and was very close to 100% wheat semolina pasta. Results also demonstrated that the contents of fat, protein and ash of pasta made from PMF (100%), WS : PMF (50 : 50) and WS : DPMF (50 : 50) were higher than that of pasta prepared using WS (100%). Reduction in phytic acid (5.56%) and trypsin inhibitor activity (5.27%) was observed with depigmentation in the WS : DPMF (50 : 50) pasta compared to WS : PMF (50 : 50) pasta. However, cooking and textural properties of pasta were not affected by depigmentation. Overall results of the study suggested that depigmentation technique was effective for formulation of acceptable pearl millet products.

Keywords: Anti-nutritional properties, cooking, depigmentation, pearl millet.

PEARL millet (*Pennisetum glaucum*), popularly called bajra, is widely cultivated in arid and semi-arid regions wherein the diverse environmental conditions with dry season and poor soil fertility are suitable for its cultivation. In India, bajra is basically utilized as a feed for cattle as well as food for the poor people to sustain their lives. India ranks first in the production of pearl millet with production of 9.1 MT and yield of 1272 kg/ha obtained from 7.1 million ha area[1]. It is reported to be rich in starch, fibre, protein, minerals and also provides higher energy than the majorly consumed cereals[2].

Pearl millet is an excellent source of nutrient, but the presence of few anti-nutritional substances and polyphenolic pigments hinder its utilization in large scale processing. Phytic acid, tannins, trypsin inhibitors, goitrogens as well as oxalic acid are known as anti-nutritional factors which reduce the bioavailability of the nutrients present in the grain. These compounds interfere with protein digestibility, mineral bioavailability and carbohydrates through inhibition of amylolytic and proteolytic enzymes. The phytic acid is present inside the germ[3] whereas, polyphenols are basically found in aleurone, pericarp as well as endosperm portion[4], which is responsible for the taste and unattractive grey colour of the grain.

The inherent dark grey colour of pearl millet grains limits its application in the preparation of food products. These polyphenolic pigments are sensitive to pH (ref. 5). Dipping of pearl millet grain in acid solution such as tamarind pods, sour milk results in reduction of grey colour of the grain. Different type of mild organic acids, e.g. tartaric, acetic, formic, or natural acidic material such as tamarind[6] are reported to be effective in lessening polyphenols and other anti-nutritional substances in decorticated seed which in turn increases consumer acceptability. The penetration rate of acidic solution towards whole grains is faster compared to dehulled grains which further results in the decolourization[7]. Dilute form of hydrochloric acid (HCl) was more suitable for efficient chemical treatment when compared to citric, as well as acetic acid, to eliminate pigments from whole grain before milling[8]. Keeping the grains soaked in diluted HCl for 15–24 h lessens major proportion of these pigments and helps in the generation of rich white grains. Limited information is reported on utilization of depigmented pearl millet for pasta preparation. In view of these, this study was envisaged to examine the effect of depigmentation of pearl millet grain on quality attributes (colour, nutritional, anti-nutritional, cooking and textural qualities) of pasta. The quality characteristics of pasta prepared from native pearl millet flour and wheat semolina were also compared during the study.

Pearl millet (cv. Pusa Composite 443) and wheat semolina (WS) were purchased from Pusa Campus, ICAR-IARI, New Delhi and the grains cleaned to remove any impurities before experimentation.

For depigmentation, about 200 g of pearl millet grains were soaked in 0.2 N HCl solution using grain : solution ratio 1 : 2 (w/v) for 18 h at ambient condition (28–32°C)[9,10]. To facilitate the depigmentation process, the grains were intermittently stirred with a glass rod during the soaking period. After soaking, the soaked solution was drained using a stainless steel sieve and grains were washed 6–7 times with distilled water. Washed pearl millet grains were blanched (98 ± 2°C for 30 sec) for removal of any remaining HCl present, and also to inhibit lipase enzyme activity so that the pearl millet products can be stored for longer duration[11]. Thereafter to bring the moisture content up to 8–10%, the blanched grains were dried

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Table 1. Formulations of pasta

Formulations	T_1	T_2	T_3	T_4
Wheat semolina (WS; %)	100	–	50	50
Native pearl millet flour (PMF; %)	–	100	50	–
Depigmented pearl millet flour (DPMF; %)	–	–	–	50

(50 ± 2°C) in a cabinet dryer (M/s Macro Scientific Works, New Delhi).

Size reduction of depigmented and native grains of pearl millet into flour was performed separately by hammer mill (Sanco, India). Grounded depigmented pearl millet flour (DPMF) and native pearl millet flour (PMF) and WS of 425 μm size were used for making pasta[12].

Four different combinations were used for making pasta, i.e. WS (T_1), PMF (T_2), blend composition of WS and PMF (T_3) and blend composition of WS and DPMF (T_4) respectively. Pasta samples were prepared using the formulations as described in Table 1.

Pasta made from 100% PMF of 780, 600, 500, 425, 313.5 and 241 μm of particle sizes was observed to be very difficult because physical integrity/stability of pasta was lost after cooking. Therefore blend composition of PMF : WS (50 : 50) was selected to prepare acceptable pasta[12].

To prepare a homogeneous mixture of flour, water was gradually added to attain moisture content of 30% (w.b.)[12]. Lumping of flour blend was avoided before processing it for extrusion. The conditioned sample was subjected to moisture estimation and the variation between targeted and actual moisture levels was kept nearly around 0.5%. This conditioned mixture was passed through an extruder (twin screw type, M/S BTPL, Kolkata, India) using a twin-screw feeder attached to it. The dough thus prepared was extruded through a concentric double cylinder type die into cylindrical hollow product wall thickness of 0.97 mm and cut into 15 mm length using a knife. The extruded pasta was dried in a cabinet dryer at 50 ± 2°C for 2 h to attain the moisture content of 8–9%. The dried samples were cooled, wrapped in biaxially oriented polypropylene (BOPP) packaging film and stored for further use.

The quality of pasta was evaluated using AOAC methods[13], i.e. for moisture content (method no. 925.10), protein content (method no. 960.52), fat content (ether extract method 920.85) and ash content (method no. 923.03) respectively, were employed. To convert nitrogen (N) into protein, conversion factor of 6.25 was used[10]. Readings of moisture, fat, protein and ash content were taken in triplicate. Colour values of dried pasta were taken in terms of International Commission on Illumination (CIE) '*L*' (lightness) and '*b**' (yellowness and blueness) using hunter colorimeter (M/s Hunter Associates Laboratory, Virginia). Before testing the samples, the colorimeter was standardized with black and white tile. Five replications were taken for colour measurements of each sample.

BIS method[14] was employed to determine the cooking loss (CL). Ten gram of pasta sample was cooked in boiling water (200 ml) with stirring until the white core disappeared, which can be confirmed by squeezing cooked pasta between two glass plates. Cooked pasta was washed with a flow of water (around 50 ml) for about 30 sec in a funnel. Water was drained for 2 min using a stainless steel sieve. Total gruel volume and the collected rinsed water was measured and gruel (20 ml) was pipetted out after mixing enough to result in even spreading of solid content into a tarred petri dish. The petri dish was placed in a hot air oven (105 ± 2°C) and the sample was dried till constant weight to obtain the solid loss in gruel and mentioned as percentage cooking loss. Three replications were taken and the average cooking loss was reported.

The textural parameters of cooked pasta were examined using Texture Analyser (model: TA + HDi®, M/s Stable Micro Systems, UK) by adopting the method reported by Limroongreungrat and Huang[15] using settings, viz. pre-test speed: 3 mm/s; test speed: 1 mm/s; post-test speed: 10 mm/s; distance: 50% in compression mode; time: 1 sec; data acquisition rate: 200 pps with cylindrical probe (p/75 mm). The TPA curve was analysed for figuring out hardness, cohesiveness, springiness and chewiness. The textural properties of the five cooked pasta samples were recorded and the average value was determined.

Phytic acid (PA) (mg/100 g) was assessed using procedure illustrated by Wheeler and Ferrel[16]. Trypsin inhibitor activity (TIA) was evaluated[17] using BAPA (Nbenzoyl-DL-arginine-P-nitroanilide hydrochloride) and TIA, expressed as TUI/mg of pasta was recorded from absorbance (410 nm) against blank sample.

All the results were expressed as mean ± standard error. Statistical analysis software (SAS) version 9.3 was adopted for analysis of variance (ANOVA) and least significant differences (LSD) and the significance of observations was accepted at 5%.

Product appearance in terms of colour is prominently correlated with consumer perception because pasta consumers generally give preference to bright yellow colour pasta[18]. It was observed that the colour of pasta prepared from different blends of ingredients differed significantly ($P < 0.05$; Table 2). Depigmentation of pearl grain improved the colour of pasta as *L*-value showed that pasta prepared after depigmentation (T_4) signifies better results

Table 2. Variation in colour of pasta as affected by depigmentation

Colour parameters	Pasta					Least significant difference
	T_1 (100%)	T_2 (100%)	T_3 (50 : 50)	T_4 (50 : 50)	*F* value	
L	58.31 ± 0.53^d	28.55 ± 0.11^a	38.56 ± 0.74^b	52.89 ± 0.08^c	924.285^S	1.54
*b**	23.68 ± 0.13^d	12.91 ± 0.21^a	17.82 ± 0.22^b	21.38 ± 0.02^c	437.290^S	0.78
Change in colour (Δ*E*)	-	30.63 ± 0.11^c	20.19 ± 0.73^b	5.84 ± 0.07^a	5.377E3^S	0.65

T_1, refers to wheat semolina pasta; T_2, refers to native pearl millet flour pasta; T_3, refers to blend of WS and PMF pasta; T_4, refers to blend of WS and DPMF pasta, values are mean ± standard error; mean with different superscripts in same row indicate significant differences at $P \leq 0.05$; ^{S}refers to significant.

Table 3. Nutritional composition of pasta as affected by depigmentation

Nutritional composition	Pasta					Least significant difference
	T_1 (100%)	T_2 (100%)	T_3 (50 : 50)	T_4 (50 : 50)	*F* value	
Protein (%)	10.06 ± 0.02^a	11.90 ± 0.02^c	11.54 ± 0.20^c	10.98 ± 0.06^b	34.384^S	0.47
Fat (%)	1.00 ± 0.01^a	4.28 ± 0.03^c	1.43 ± 0.14^b	1.43 ± 0.04^b	3.305E3^S	0.09
Ash (%)	0.47 ± 0.22^a	1.16 ± 0.12^c	0.73 ± 0.01^b	0.73 ± 0.01^b	276.999^S	0.06

Abbreviations and explanations same as in Table 2.

as compared to PMF pasta (T_2) or WS : PMF (50 : 50) pasta (T_3; Table 2). This might be due to the presence of polyphenolic pigments in grain, which are sensitive to pH (ref. 5). Hence, soaking of grain in acid solution leached out these pigments in soaked medium, thus improving the colour of grain. Similar effect of acid soaking on colour improvement was also observed in flat bread prepared from pearl millet[8,9].

In terms of *L*, *b** and Δ*E* values, the colour of depigmented PMF based pasta was observed to be close to WS pasta (T_1). Change in colour (Δ*E*) in depigmented pasta (T_4) was 5.84, whereas the corresponding value for T_2 and T_3 pasta samples was 20.19 and 30.63 respectively when compared to WS pasta. Rathi *et al.*[10] also reported that the process of depigmentation significantly ($P < 0.05$) enhanced colour of pasta and was at par with pasta made using refined flour. Pasta of light colour was developed from depigmented pearl millet grain while grey colour pasta was noticed from native pearl millet grain.

The nutritional composition (protein, fat and ash content) of different pasta is summarized in Table 3. The protein content of T_1, T_2, T_3 and T_4 pasta was found to be 10.06%, 11.90%, 11.54% and 10.98% respectively. These protein values were correspondingly higher than that of T_1, viz. T_2 (18.29%), T_3 (14.71%) and T_4 (9.15%) respectively. Similarly, Archana *et al.*[19] emphasized that pearl millet has better overall nutritive value than wheat. Protein content of pasta prepared from pearl millet and chickpea flour (4 : 1) was 53.2% and that of pasta prepared from depigmented pearl millet and chickpea flour (4 : 1) was 41.46% higher than refined flour pasta[10].

As observed, depigmentation resulted in 8.38% and 5.10% decrease in protein content of T_4 pasta compared to T_2 pasta (100% PMF) and T_3 pasta (blend of WS : PMF) respectively. A similar report presented by Rathi *et al.*[10] substantiating that the protein content of DPMF pasta showed reduction by 7.46% when compared to PMF pasta. During depigmentation, reduction in protein content could be attributed partially to hydrolysis and protein leaching while soaking in acid[9] and blanching[20].

Fat content of 100% WS pasta (T_1) was 1% as against 4.28%, 1.43% and 1.43% in pasta prepared from 100% PMF (T_2), blend of WS : PMF (T_3) and blend of WS : DPMF (T_4) respectively (Table 3). The fat content of pearl millet based pasta, i.e. T_2, T_3 and T_4 was significantly higher than pasta prepared from WS (T_1). Abdalla *et al.*[21] and Archana *et al.*[19] reported high range of fat (2.70–7.88%) in pearl millet through proximate analysis. This high proportion of inherent fat in grain could have subsequently affected the fat percentage of pearl millet pasta. Depigmentation indicated non-significant difference between T_3 and T_4 pasta in terms of fat content (Table 3).

Flour with low ash content is an advantage for pasta/noodle, as ash content is responsible for noodle discolouration. The ash content of sample T_1, T_2, T_3 and T_4 was 0.47%, 1.16%, 0.73% and 0.73% respectively (Table 3). This variation may be attributed to the kind of ingredients used for preparation. Ash percentage of native pearl millet flour pasta (2.40%) and depigmented pearl millet flour pasta (2.35%) was higher than refined flour pasta (1.39%)[10].

Among the four samples considered in the study, antinutritional factors (PA and TIA) were absent in pasta prepared from 100% WS (T_1), whereas pasta sample (T_2) had maximum PA (207.82 mg/100 g) and TIA (7.92 TUI/mg)

Table 4. Anti-nutritional factors of pasta as affected by depigmentation

Anti-nutritional factors	Pasta					Least significant difference
	T_1 (100%)	T_2 (100%)	T_3 (50 : 50)	T_4 (50 : 50)	F value	
PA (mg/100g)	0.00^a	207.82 ± 0.82^d	106.05 ± 0.52^c	100.15 ± 0.36^b	6.713E3$^\$$	3.58
TIA (TUI/mg)	0.00^a	7.92 ± 0.01^d	4.93 ± 0.01^c	4.67 ± 0.01^b	4.480E3$^\$$	0.17

PA, Phytic acid; TIA, trypsin inhibitors activity.

Table 5. Cooking and textural properties of pasta as affected by depigmentation

Cooking and textural properties	Pasta					Least significant difference
	T_1 (100%)	T_2 (100%)	T_3 (50 : 50)	T_4 (50 : 50)	F value	
Cooking loss (%)	5.39 ± 0.10^a	8.27 ± 0.43^c	7.56 ± 0.04^b	7.22 ± 0.56^b	133.423$^\$$	0.37
Hardness (N)	20.81 ± 0.46^c	7.48 ± 0.09^a	9.95 ± 1.21^b	9.37 ± 0.17^b	958.586$^\$$	0.67
Cohesiveness	0.68 ± 0.03^c	0.52 ± 0.05^a	0.61 ± 0.01^b	0.61 ± 0.10^b	180.800$^\$$	0.02
Springiness (mm)	1.03 ± 0.02^b	0.59 ± 0.01^a	1.06 ± 0.04^c	1.07 ± 0.24^c	2.150E3$^\$$	0.06
Chewiness (N mm)	14.52 ± 0.59^c	2.30 ± 0.28^a	6.15 ± 0.61^b	5.91 ± 0.05^b	1.536E3$^\$$	0.46

Abbreviations and explanations same as in Table 2.

compared to those prepared from a blend of WS : PMF (106.05 mg/100 g and 4.93 TUI/mg) and blend of WS : DPMF (100.15 mg/100 g and 4.67 TUI/mg) (Table 4). The relatively higher content of PA and TIA of pasta samples (T_2 and T_3) could be credited to the existence of substantial quantity of anti-nutrients in raw or native pearl millet[22]. Anti-nutrients, particularly phytic acid, combine with protein to configure a protein–mineral complex that prevents the enzymatic degradation of protein. Decrease in PA (5.56%) and TIA (5.27%) in the pasta prepared from a blend of WS : DPMF (T_4) compared to a blend of WS : PMF (T_3) was significant ($P \leq 0.05$); however reduction of 52% in PA and 41% in TIA was observed when compared to pasta prepared from 100% PMF (Table 4). Leaching of anti-nutrients and swelling, as well as rupturing of starch granules during depigmentation appears to be the prominent reason for this decline in anti-nutritional factors. The application of heat during processing might have contributed to the destruction of anti-nutrients, by breakdown and modification of protein of high molecular weight or by destroying heat labile protease inhibitor[10]. In addition, diminishing anti-nutrients and simultaneous improvement in the *in vitro* protein digestibility was observed by 12 h soaking of fababean and ricebean[23].

Cooking loss was lowest (5.39%) in 100% WS pasta (T_1) and highest (8.27%) in 100% PMF pasta (T_2), respectively (Table 5). The pertinent reason for this variation is the addition of non-gluten flour in wheat flour, which in turn weakens the pasta network by virtue of which the starch particles were together. While cooking, the loss of solids is associated to the solubilization of loosely bound gelatinized starch from the product surface[24]. Difference in cooking loss of pasta with and without pigment in pearl millet was very small.

The observed textural properties such as hardness, cohesiveness, springiness and chewiness varied from 7.48 to 20.81 N, 0.52 to 0.68, 0.59 to 1.21 mm and 2.30 to 14.52 N mm (Table 5). Pasta prepared from 100% WS (T_1) had comparatively better textural properties than T_2, T_3 and T_4 samples. Decrease in the textural properties of pearl millet-based pasta might be due to the absence or less amount of gluten content and gluten composition[25]. However, non-significant difference was observed between the pasta prepared from blend of WS : DPMF (T_4) and blend of WS : PMF (T_3) (Table 5) which emphasized that depigmentation did not alter the textural properties of pasta.

From the present study, it was observed that the main factor which hinders extensive utilization of pearl millet grain is the presence of grey colour which can be improved by depigmentation. In terms of L, b^* and ΔE values, the colour of depigmented PMF pasta was observed to be close to wheat semolina pasta. Nutritional composition (protein, fat and ash content) of pasta did not alter after depigmentation. Moreover, significant reduction in anti-nutritional factors, viz. TIA and PA was observed due to depigmentation. Also, cooking and textural properties of depigmented pearl millet pasta were on par with the pasta prepared from blend of wheat semolina and native pearl millet flour. Overall, depigmentation of pearl millet provides an effective way for improving and developing acceptable pearl millet pasta commercially.

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Adopt and adapt nature's design principles to create sustainable aquaculture systems

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Sustainable development of aquaculture faces many constraints. An approach that offers solutions to these challenges is emulating nature's patterns and strategies. There are many elements of sustainability employed by nature that can be adopted for aquaculture systems through necessary adjustments (or adaptations). Analysis of empirical data generated by a series of experiments on different aquaculture systems generated new knowledge of practical importance. An outcome of the analysis pertaining to two important aspects of aquaculture, the sex control in captive stocks of commercially important protogynous hermaphrodite grouper and the operation of integrated multi-trophic aquaculture systems is presented here. Both cases serve as outstanding examples of the relevance of examining and applying nature's principles for finding sustainable solutions to aquaculture problems.

Keywords: Aquaculture, nature's design, systems approach, sustainability.

WITH the capture fisheries stagnating and declining, aquaculture has increased its contribution to global seafood supplies to more than 50%. It is the only farming system that can bridge the gap between supply and demand of seafood. However, sustainability of aquaculture systems remains an elusive goal. Applying nature's principles in producing organisms that constitute our seafood raises hope because of their core elements of sustainability. Adapting them to aquaculture systems can address the

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