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Effect of processing on physical characteristics of finger millet (*Eleusine coracana*) varieties

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Abstract
Finger millet is one of the important small millets cultivated in many South Asian and African countries. An investigation was undertaken to study the effect of processing on physical characteristics of finger millet varieties. Five varieties of finger millet namely GPU 66, GPU 67, GPU 71, MR 6 and PR 202 were investigated for their physical characteristics before and after processing such as malting and popping. Colour, 1000 seed weight, 1000 seed volume, hydration capacity, hydration index, swelling capacity, swelling index, specific gravity, bulk density, percent germination, malt recovery and percent popping were analysed for raw, malted and popped finger millet varieties. Among these physical characteristics 1000 seed weight, 1000 seed volume, hydration capacity, hydration index, swelling capacity, swelling index of germinated was found to be higher followed by raw and popped finger millet varieties. However the mean specific gravity and bulk density was found to be high in raw followed by malted and popped. The mean percent germination (99.0 %), malt recovery (82.0 %) and popping (76.0 %) was found to be higher in GPU 71.

Keywords: Finger millet, hydration capacity, swelling capacity, malting, popping

Introduction
Finger millet (*Eleusine coracana*) also known as ragi is one of the millet which is often referred to as a coarse cereal, the food uses of which are receiving considerable attention by food scientists and technologists in the recent years. Finger millet grains are found in different shapes, sizes and colours with the predominant colour being brown. In recent years, finger millet or ragi has gained importance because of its nutritional strength in terms of dietary fibre, functional fibre, starch pattern as well as high calcium, iron and zinc contents. Although millets are nutritionally superior, the non-availability of processed millets in ready to use form has limited their use and acceptability. Millets are therefore confined to traditional consumers and also to the people of lower economic strata. The knowledge of the physical properties will be useful in new product development. Hence the present study was carried out to know the effect of processing such as malting and popping on its physical characteristics.

Material and Methods
Five finger millet (*Eleusine coracana*) varieties selected for study were procured from All India Co-ordinated Small millets Improvement Project, University of Agricultural Sciences, Bengaluru. The varieties selected were GPU 66, GPU 67, GPU 71, MR 6 and PR 202. They were cleaned to remove foreign materials and impurities. Further were subjected to malting and popping.

Malting of Finger millet: Finger millet seeds were washed with water for 5 times and soaked in water for 5 hrs. Excess water was drained, seeds were tied in a muslin cloth and 5 kg weight was kept on it. These seeds were germinated at 27± 3 º C for 24 hr and dried in shade for 2 days. The germinated shade dried finger millet seeds were subjected to kilning and devegetated. These seeds were grounded into flour by using the electric grinder (Plate 2) (Malleshi and Desikachar, 1986) [5].

Popping of Finger millet: After determining the moisture in the sample by oven drying methods, water was sprinkled on the grain to raise the moisture content to 19 percent, mixed well and grain equilibrated in a closed airtight container for 24 hrs prior to popping. After 24 hours the equilibrated grain were added in an iron frying pan, the temperature of which was maintained at 175-200º C. When popping sound was stopped the pan was removed from the flame (Plate 3) (Malleshi and Desikachar, 1981) [7].

Munsell soil colour chart (1952) was used to identify the colour of finger millet varieties.

The physical characteristics of the research sample in its raw, malted and popped form were analysed for 1000 seed weight (Balasubramanian and Vishwanathan, 2010) [3]

1000 seed volume, hydration capacity, hydration index, swelling capacity, swelling index, specific gravity (William *et al.*, 1983; bulk density (Narayana and Rao, 1982) [10]; grain to flour ratio (Shashi, B.K, 2005) [12]; percent germination (Aykroyd and Doughty, 1964) [2]; malt recovery (Malleshi *et al.*, 1986) [5] and popping percent (Malleshi and Desikachar, 1981) [7].

Statistical Analysis

For comparison of nutrient content of raw, malted and popped finger millet two way analysis of variance test was applied on the means of two replications for different varieties.

Results and Discussion

The colour of brown varieties ranged from light red (MR 6) to dark reddish brown (GPU 67) and colour of white finger millet variety was pale yellow (Table 1, Plate 1). The difference in colour of grains is due to varietal difference.

Percent germination of different finger millet varieties under study ranged from 98 to 99 per cent (Table 2) which is in tune with findings of study by Kumari and Srivastava (2000) [6] on 'Nutritive value of malted flours of finger millet genotypes and their use in the preparation of Burfi'.

Percent malt recovery of different finger millet varieties which ranged from 75 to 82 per cent (Table 2) in the present study is in tune with the findings of the study conducted by Pawar and Pawar (1997) [11] and Malleshi and Klopfenstein (1998) [5] on 'Nutrient composition and amino acid contents of malted sorghum, pearl millet and finger millet and their milling fractions'. The variation in malt recovery may be due to the moisture and fibre content in the varieties. Higher the moisture and fibre content lower is the malt recovery.

A study conducted by Shukla *et al* (1986) [13] on of finger millet for puffing yield found that puffing yield ranged from 66 to 95.3 per cent. But the popping percent of the finger millet varieties under study ranged from 31 to 76 per cent (Table 2) which is in tune with the findings of the study conducted by Shukla *et al.*, (1986) [13] on eight varieties of finger millet for puffing yield but not on par with the findings of Shukla *et al.*, on eight varieties of finger millet.

The 1000 seed weight of raw finger millet genotypes reported by Kumari and Srivastava (2000) [6] ranged from 2.42 to 3.23g. A study conducted by Balasubramanian and Viswanathan (2010) [3] on the influence of moisture content on physical properties of minor millets reported the 1000 kernel weight to range from 2.3 to 6.1 g. However the 1000 kernel weight of the samples under study ranged from 3.07 to 3.28g in raw, 4.1 to 4.3g in germinated and 1.78 to 2.12g in popped (Table 3) which are in tune with the findings of Balasubramanian and Viswanathan. This difference in 1000 seed weight may be attributed to the moisture content of the samples as reported by Singh and Goswami (1996) [14] and also due to genotype variation.

The 1000 seed volume of raw finger millet varieties ranged from 2.2 to 12.9 ml as reported by Hadimani and Malleshi (1995) [5] in thirty eight pearl millet varieties. Similarly Shashi, B.K (2005) [12] also reported 1000 seed volume of eight varieties of finger millet which ranged from 2.6 to 3.6 ml. Similar trend was observed in raw finger millet varieties under study which ranged from 3.3 to 3.7ml (Table 3). The seed volume was high in case of germinated finger millet which may be due to its high seed weight compared to raw and popped finger millet. Lower seed volume was observed in popped finger millet which may be due to lower seed weight and moisture content in it.

Hydration capacity of raw, malted and popped finger millet varieties ranged from 0.63 to 0.75, 1.15 to 1.81 and 0.51 to 0.69 respectively (Table 3) which was in tune with the findings of Vidhyavati (2001) where in hydration capacity of raw samples ranged from 0.82 to 1.45. A study conducted by Srivastava and Batra (1998) [6] also reported that hydration capacity of different finger millet varieties in raw form ranging from 0.20 to 0.52 in popped finger millet.

The hydration index of raw finger millet varieties under study ranged from 0.19 to 0.22 with a mean of 0.20 (Table 3) which is on par with the results of Shashi, B.K (2005) [12] wherein the hydration index of different finger millet varieties ranged from 0.18 to 0.28. Hydration index of germinated finger millet was found to be higher compared to raw and popped finger millet. The reason might be due to high moisture content and seed weight of the germinated seeds.

Among raw, malted and popped finger millet varieties under study, malted form of finger millet had the highest swelling capacity compared to raw and popped. The swelling capacity of raw finger millet varieties under study ranged from 1.25 to 1.80 (Table 4) which is in tune with findings of a study conducted by Shashi, B.K (2005) [12]. The variations in the swelling capacity of different forms of finger millet under study may be due to the difference in seed volume.

The results of swelling index of raw finger millet varieties under study ranged from 0.35 to 0.48 (Table 4) which followed the similar trend as reported by Shashi, B.K (2005) [12] in the study on "Evaluation of physicochemical properties of new Indo-African finger millet (*Eleusine coracana* Gaertn.) Genotypes". However the swelling index of the processed forms was found to be higher.

Specific gravity of the raw finger millet varieties under study ranged from 1.03 to 1.15 (Table 5) which was on par with the findings of Shashi, B.K, 2005 [12]. However, it was observed that the specific gravity decreased in the malted and the popped forms of finger millet varieties.

The mean bulk density of raw finger millet varieties was found to be higher than that of malted and popped form of finger millet. The bulk density of the raw finger millet ranged from 0.67 to 0.75 g/ml in a study conducted by Vidhyavati (2001). The results of present study pertaining to bulk density of raw finger millet also followed the similar range (0.69 to 0.80 g/ml) (Table 5). Bulk density decreased after malting and popping of the finger millet. The decrease in bulk density of the germinated millet flours would be an advantage in the preparation of supplementary foods (Akubor and Obiegbuna, 1999) [1]. Similarly a study conducted by Balasubramanian and Viswanathan (2010) [3] reported that at higher moisture levels, bulk density will be higher. Similar trend was observed in the present study where in the raw finger millet flour with high moisture content had higher bulk density.

The grain to flour ratio in case of raw finger millet was found to be higher compared to malted and popped form of finger millet. The results of grain to flour ratio of raw finger millet in the present study ranged from 96.0 to 99.5 (Figure 1) which is in tune with the findings of Shashi, B.K (2005) [12]. The malt yield in the present study ranged from 75 to 82 per cent. Similarly a study conducted by Begum, 1998 on malting of different varieties of finger millet showed that the malt yield ranged from 59 to 66 per cent, Pawar and Pawar (1997) [11] research findings also showed that the malt yield was around 85 per cent in case of foxtail millet. The results of the present study for grain to flour ratio of malted flour were on par with the results of Begum (1998) [4] and Pawar and Pawar. The popping yield of pearl millet ranged from 8.3 to 77.1 percent

in a study conducted by Hadimani and Malleshi (1995) [5]. Similar trend was observed in popped grains under study (31 to 76 per cent).

Thus the investigation on five different finger millet varieties revealed that significant difference existed between the finger millet varieties in raw form with respect to both physical characteristics and also between the raw and processed finger millet. All the varieties exhibited good malting and popping characteristics with GPU 71 having highest malting and popping percent. GPU 71 with highest malting and popping per cent can be exploited for developing malt and popped finger millet based products. Finger millet, a nutritious cheaper grain can be used for preparing diversified products in day to day life.

Table 1: Colour of the raw finger millet grains

Varieties	Colour of the grains
GPU 66	Light red (4/6)
GPU 67	Dark reddish brown(3/4)
GPU 71	Pale yellow(7/4)
MR 6	Red (5/8)
PR 202	Reddish brown (4/4)

Measured by visual observation (Munsell soil colour chart, 1952)

Table 2: Germination, Malt recovery and Popping percent of finger millet varieties

Varieties	Germination %	Malt recovery %	Popping %
GPU 66	98	78	66
GPU 67	98	79	59
GPU 71	99	82	76
MR 6	98	75	31
PR 202	98	76	54
Mean	98.2	78	57.2
	SE	CD at 5%	F value
V	0.387	1.167	*
PM	0.300	0.904	*
V X PM	0.6708	2.0213	*

*Significant at p (≤ 0.05)
V- Variety
PM-Processing methods
V X PM- Variety X Processing method

Table 3: Physical characteristics of raw, malted and popped finger millet

Varieties	1000 seed weight (g)			1000 seed volume(ml)			Hydration capacity			Hydration index		
	Raw	Germinated	Popped	Raw	Germinated	popped	Raw	Germinated	Popped	Raw	Germinated	Popped
GPU 66	3.21	4.30	2.12	3.50	4.60	2.60	0.63	1.21	0.51	0.19	0.28	0.24
GPU 67	3.14	4.12	1.98	3.30	4.20	2.50	0.66	1.25	0.61	0.21	0.30	0.30
GPU 71	3.28	4.25	1.78	3.60	4.50	2.10	0.75	1.81	0.69	0.22	0.42	0.38
MR 6	3.28	4.30	1.90	3.70	4.70	2.70	0.64	1.25	0.60	0.19	0.29	0.31
PR 202	3.07	4.10	1.89	3.50	4.20	2.50	0.63	1.15	0.59	0.20	0.28	0.31
Mean	3.19	4.21	1.93	3.52	4.44	2.48	0.66	1.33	0.60	0.20	0.31	0.30
	S.Em±	CD	F value	S.Em±	CD	F value	S.Em±	CD	F value	S.Em±	CD	F value
V	0.0007	0.002	*	0.0149	0.0449	*	0.0088	0.0266	*	0.021	0.0632	*
PM	0.0005	0.0015	*	0.0116	0.0348	*	0.0068	0.0206	*	0.0162	0.0489	*
V X PM	0.0011	0.0034	*	0.0258	0.0779	*	0.0153	0.046	*	0.0489	-	NS

*Significant at p(≤0.05)
NS Non significant
V- Variety
PM-Processing methods
V X PM- Variety X Processing methods

Table 4: Swelling capacity and Swelling index of raw, malted and popped finger millet

Varieties	Swelling capacity			Swelling index		
	Raw	Germinated	Popped	Raw	Germinated	Popped
GPU 66	1.40	2.50	1.80	0.40	0.54	0.69
GPU 67	1.30	2.60	1.70	0.39	0.61	0.68
GPU 71	1.60	2.90	2.10	0.44	0.64	1.38
MR 6	1.80	2.80	2.10	0.48	0.59	0.77
PR 202	1.25	2.50	2.00	0.35	0.59	0.80
Mean	1.47	2.66	1.94	0.41	0.59	0.86
	S.Em±	CD	F value	S.Em±	CD	F value
V	0.0269	0.081	*	0.0044	0.0133	*
PM	0.0208	0.0627	*	0.0034	0.0103	*
V X PM	0.0465	0.1403	*	0.0076	0.0203	*

*Significant at p(≤0.05), V- Variety, PM-Processing methods, V X PM- Variety X Processing methods

Table 5: Specific gravity and Bulk density of raw, malted and popped finger millet varieties

Varieties	Specific gravity			Bulk density(g/ml)		
	Raw	Malted	Popped	Raw	Malted	Popped
GPU 66	1.10	0.86	0.76	0.79	0.75	0.63
GPU 67	1.05	0.81	0.78	0.76	0.72	0.59
GPU 71	1.15	0.82	0.83	0.69	0.70	0.57
MR 6	1.06	0.79	0.81	0.73	0.69	0.57
PR 202	1.03	0.81	0.79	0.80	0.78	0.65
Mean	1.07	0.81	0.79	0.75	0.72	0.60
	S.Em±	CD	F value	S.Em±	CD	F value
V	0.01	0.0302	*	0.0056	0.0168	*
PM	0.0078	0.0234	*	0.0043	0.013	*
V X PM	0.0174	0.0523	*	0.0097	-	NS

*Significant at p (≤ 0.05)
NS Non significant
V- Variety
PM-Processing methods
V X PM- Variety X Processing methods

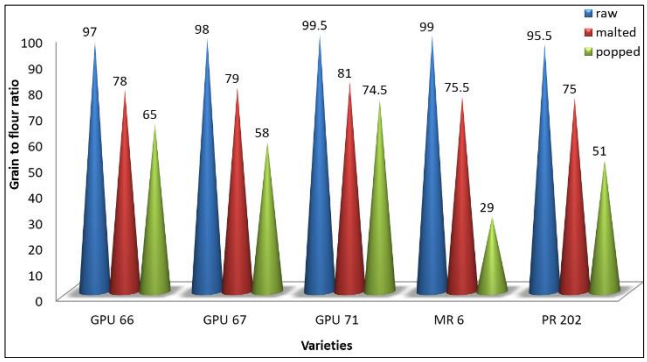

Fig 1: Grain to flour ratio of raw, malted and popped finger millet varieties

Plate 1: Raw finger millet varieties

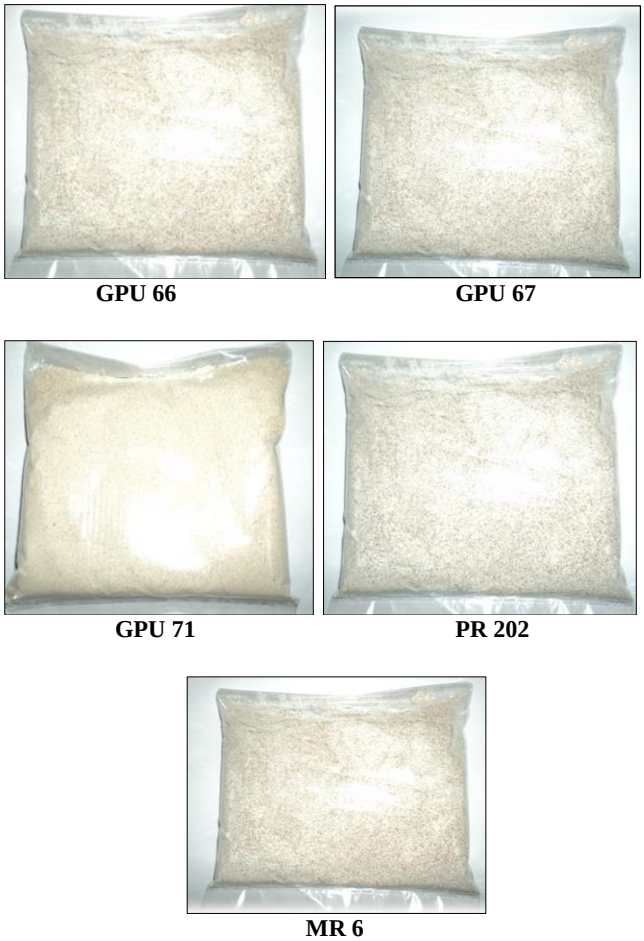

Plate 2: Malted finger millet varieties

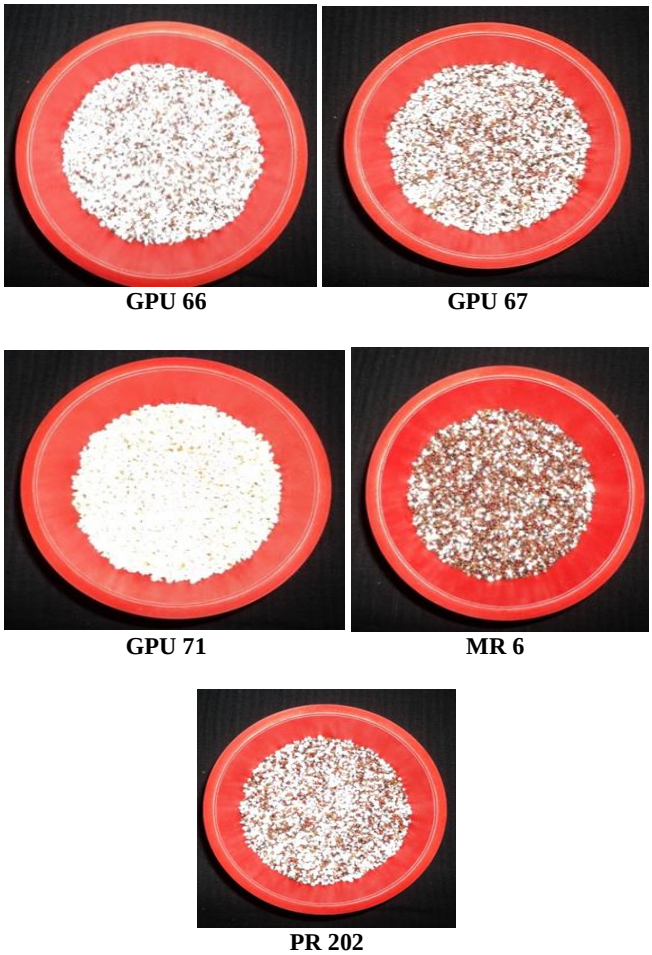

Plate 3: Popped finger millet varieties

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