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RESEARCH ARTICLE

High Popping Quality Finger Millet (*Eleusine coracana*) Genotypes

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Abstract
Finger millet grains are rich in micronutrients, but their bioavailability to the human body is limited by its anti-nutritional factors. The popping of grain is one of the easy and economical household processing techniques that reduce the anti-nutritional factors. The popped grain can be used in the preparation of value-added products like weaning foods, noodles, and ready-to-eat products. In order to identify finger millet genotypes for high popping quality, grains of 85 genotypes were evaluated for popping quality using an iron frying pan by adjusting the grain moisture content to 19%. The popping ranged from 16.6% (*Pichakaddi ragi*) to 87.1% (Co-10) with a mean of 54.1%. Genotypes Co-10, Indaf-3 and *Karikaddi ragi* showed a high popping percentage (>80.0%). The brown-colored grain was better for popping (55.7%) than white grain (34.5%), and the freshly harvested grains were better than grain stored for three years.

Keywords: Finger millet, Popping, Grain color, Landraces, Stored grain.

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Introduction

Finger millet is known for its health benefits and is a staple food in southern Karnataka, India and many parts of eastern and central Africa. It is a rainfed crop cultivated under adverse conditions (Davis *et al*., 2019). It is rich in calcium, iron, zinc, fiber and essential amino acids like lysine and has several health benefits (Chethan and Malleshi, 2007; Chandra *et al*., 2016; Hiremath *et al*., 2018). Finger millet is consumed as ragi balls, lumps, porridge, malt and rotis (Indian flatbread). However, the anti-nutritional factors such as phytic acid, tannin, oxalic acid and trypsin inhibitor activity in the seed coat decrease the bioavailability of micronutrients like iron and zinc (*Chauhan and Sarita, 2018*). Products prepared from popped grains were found to increase the bio-accessibility of iron (5%) and zinc (18%) as compared to whole grain products (Krishnan *et al*., 2012; Chauhan and Sarita, 2018). Popped grain is used extensively in the preparation of value-added products like weaning foods, noodles, and ready-to-eat products that are crunchy and porous (Singh and Raghuvanshi, 2012). Besides, the popped products will have a pleasant aroma and an acceptable taste (Lewis *et al*., 1992; Mirza *et al*., 2015). The popping increases the solubility and digestibility of starch and leads to a low bulk density and pleasing texture (Ramashia *et al*., 2019). Popping enables easy digestion due to the pre-cooked hydrolysis of proteins and structural changes. Genotypes with superior popping quality can be effectively utilized in the food processing industry to ensure enhanced nutrient availability in the products. Hence, the present investigation aimed to identify the best-popping varieties amongst the released varieties of finger millet in the country and study the factors influencing the popping quality.

Materials and Methods

Popping is the simplest, inexpensive, and quickest traditional method of processing of finger millet grain. The most widely used popping technique in rural households is by heating the sand mixed with a small quantity of grain in an iron frying pan. The principle involved in popping is that, during heating the grains will experience a high temperature for a short period (HTST). During heating, super-heated vapors develop inside the grain, the grain is cooked, and the endosperm expands. During the expansion of the endosperm, the vapors will escape through the micropores with great force, leading to the popping of grains.

Grains of 85 finger millet genotypes (including land races) grown during *Kharif* 2013 in two replications at the All India Coordinated Small Millets Improvement Project on Small Millets were pooled, cleaned and used for popping. The process of popping was carried out in three replications at the All India Coordinated Research Project on Food and Nutrition, University of Agricultural Sciences, GKVK, from March to April 2014. The initial grain moisture content was measured by taking 10 g of sample from each variety and oven-drying at 105°C for four hours.

$$\text{Moisture content (\%)} = \frac{\text{Initial weight (g)} - \text{Oven-dried weight (g)}}{\text{Initial weight (g)}} \times 100$$

After determining the initial grain moisture content for each variety, 20 g of grain samples in three replications were sprayed, with the required volume of water to adjust the grain moisture to 19%. Such samples were mixed well and equilibrated for 24 hours in desiccators (Malleshi and Desikachar, 1981) and used for popping. These grains were placed in the iron frying pan containing fine sand (0.85 mm) as a heat exchange medium, mixed and heated as sufficient for popping (approx. 270°C). When the popping sound stopped, the pan was removed immediately from the flame, cooled, and sieved through a 0.85 mm sieve to remove the sand. The leftover popped grains in the sieve were separated into completely popped, partially popped and un-popped grains manually, weighed, and the popping percentage was calculated. The data were analyzed in a completely randomized design in OPSTAT statistical software replications (Sheoran *et al*., 1998).

$$\text{Complete Popping yield (\%)} = \frac{\text{Weight of completely popped grains}}{\text{Weight of popped (complete + partial) grains + un-popped grains}} \times 100$$

$$\text{Partial Popping yield (\%)} = \frac{\text{Weight of partially popped grains}}{\text{Weight of popped (complete + partial) grains + un-popped grains}} \times 100$$

$$\text{Total Popping yield (\%)} = \frac{\text{Weight of popped (complete + partial) grains}}{\text{Weight of popped (complete + partial) grains + un-popped grains}} \times 100$$

Pearson correlations were performed between initial grain moisture content and popping percentage using the data on popping percentage. The brown and white-grain genotypes were separated and compared for their popping quality.

Furthermore, to compare the freshly harvested grain with stored grain for a given period, the popping performance of three years old (aged) seeds of six genotypes grown in Kharif, 2016 (harvested in January 2017) were collected and popped during May-June, 2020. In another sub-study, the seeds of cv. GPU-28 and PR-202 grown during Kharif, 2016, 2018, and 2019 (harvested in Jan 2017, 2019, and 2020, respectively) were collected and popped during May–June 2020.

Results and Discussion

Genetic Diversity in Popping Performance

The productivity of finger millet is higher than that of major rainfed crops like sorghum (www.indiaagristat.com) and has superior nutritional qualities (Chandra *et al*., 2016). However, the use of whole grains has a limitation on the bioavailability of micronutrients. Processing whole grain by popping and preparing products out of popped grain can improve the bioavailability of micronutrients by reducing the anti-nutritional factors (Krishnan *et al*., 2012). In the present study, the popping percentage differed significantly amongst 85 genotypes and ranged from 16.6 (cv. *Picha kaddi ragi*) to 87.1% (cv. Co-10), with a mean of 54.1% (Table 1). Similarly, a wide range of popping from 31.0 to 76.0% (Hiremath and Geetha, 2019), 55.0 to 84.0% (Chaturvedi and Srivastava, 2008) and 68 to 74% (Sneha *et al*., 2018 in white finger millet) has been reported previously. The majority of genotypes (56 out of 85) recorded >50 % popping (Table 1). The genotypes Indaf-3, *Karikaddi ragi* and Co-10 were high-popping types with > 80% (Table 1). Malleshi and Desikachar (1981) also reported that cv. Indaf-3, Purna and PR-202 were high-popping types. The genotypes *Picha kaddi ragi*, PRM-802 and *Jenu Bonda ragi* were poor popping genotypes (<20%; Table 1).

Completely popped grains are preferred over partially popped grains in the preparation of ready-to-eat and other products. Among the popped grains, the mean weight of completely popped grains was high (31.8%) when compared to the partially popped grains (22.3%). The completely popped grains were highest in cultivated cv. Co-10 (55.9%), followed by Indaf-3 (58.1%), GN-4, PRM-2, Indaf-9, Purna and KMR-301 in addition to a landrace *Karikaddi ragi* with more than 62.2% (Figure 1; Table 1). The higher popping quality of grain could be due to grain hardiness, hydration capacity and higher protein solubility (Mirza *et al*., 2015). These selected genotypes are better for both household and industrial use.

Effect of Grain Moisture Content on Popping Performance

As grain moisture content is important in determining the popping quality, the influence of initial grain moisture

Table 1: Genotypic variation in popping quality (%) of finger millet

Sl. No.	*Genotype*	*Year of release*	*Parentage*	*State*	*Moisture (%)*	*Complete (%)*	*Partial (%)*	*Total (%)*
1	GPU-28 (check)	1998	Indaf-5 x IE-1012	Kar	10.2	29.7	27.2	56.9
2	PR-202 (check)	1976	Selection	AP	11.4	33.6	45.2	78.8
3	Co-10	1976	Selection	TN	10.0	55.9	31.2	87.1
4	Indaf-3	1976	Cauvery x IE-927	Kar	11.1	58.1	25.2	83.3
5	Kari kaddi ragi*		Local	Kar	10.7	62.2	19.6	81.8
6	GN-4	2000	Selection	Gujarath	11.0	57.5	20.2	77.7
7	ES-11	1939	Selection from Gidda ragi	Kar	11.1	45.2	28.6	73.8
8	PRM-2	2010	Pure line selection	UK	10.5	54.4	19.1	73.5
9	GPU-66	2009	PR-202 x GPU-28	Kar	11.6	46.6	25.8	72.4
10	Indaf-9	1985	K-1 x IE-980 R	Kar	10.2	53.3	18.2	71.5
11	Purna	1959	Co-1 x Aruna	Kar	8.2	52.5	18.8	71.3
12	RAU-3			Bihar	10.9	34.5	36.5	71.0
13	Hullubele*			Kar	11.4	47.7	23.0	70.7
14	BM-1	1985	Pureline selection	Bihar	10.8	44.2	26.0	70.2
15	Co-12	1985	Selection from PR-722	TN	9.4	48.6	21.6	70.2
16	Co-14	2004	Malawi-1305 x Co-13	TN	11.0	46.8	23.4	70.2
17	Indaf-8	1982	Hullubele x IE-929	Kar	9.7	51.5	18.4	69.9
18	Dapoli-1	1994	Selection from mutant	MR	11.7	36.8	32.9	69.7
19	KMR-301	2009	MR-1 x GE-1409	Kar	10.1	52.8	16.8	69.6
20	Bhairabi	1999	Mutant of Bhudha Madua	Odisha	11.2	41.6	27.4	69.0
21	Co-13	1989	Co-7 x TAH-107	TN	10.8	47.2	21.8	69.0
22	Paiyur-2	2008	VL-145 X Selection-10	TN	12.3	41.4	26.5	67.9
23	PES-110	1985	Pureline selection	Bihar	10.3	40.2	27.3	67.5
24	HR-911	1985	UAS-1 x IE-927	Kar	11.2	41.8	25.7	67.5
25	RAU-8	1989	BR-407 x Ranchi local	Bihar	10.5	42.4	23.9	66.3
26	Saptagiri	1995	MR-1 x Kalyani	AP	10.1	50.3	14.1	64.5
27	VR-708	1998	Pure line selection-local	AP	11.0	46.3	17.6	63.9
28	TRY-1	1989	Pureline selection from HR-374	TN	10.3	39.6	23.2	62.8
29	A-404	1993	Introd. From AP	Bihar	10.3	36.0	26.6	62.6
30	Nashini			MR	10.0	40.9	21.7	62.6
31	Kalyani	1972	Pureline selection from CR-652	AP	10.0	35.6	26.0	61.6
32	VR-762	2006	Pureline selection from VMVC-134	AP	10.4	41.3	20.3	61.6
33	PRM-1	2006	Selection-Local	UK	11.0	33.2	28.3	61.5
34	VL-149	1991	VL-204 x IE-882	UK	10.3	39.2	21.9	61.1
35	Shakti	1972	R-0013 x H-22	Kar	12.4	32.3	28.2	60.5
36	GE-4			UP	9.0	34.7	25.6	60.3
37	Hasiru kaddi ragi*			Kar	10.6	28.2	32.0	60.2
38	GPU 70			Kar	10.3	33.8	26.0	59.8
39	VR-847	2009	GPU-26 x L-5	AP	11.4	43.7	16.0	59.7
40	KMR-305			Kar	10.3	34.7	24.1	58.8
41	MR-6	2004	African White x ROH-2	Kar	11.5	33.5	24.3	57.8
42	Indaf-5	1977	Cauvery x IE-929	Kar	10.7	33.8	23.3	57.1
43	Dibyasinha	1971	Mutant of AKP-7	Odisha	11.2	33.9	23.1	57.0
44	MR-1	1990	Hamsa x IE-927	Kar	11.0	29.4	25.8	57.2
45	Chilka	2001	GE-68 x GE-156	Odisha	10.4	29.7	27.2	56.9

46	L-5	1999	Malawi x Indaf-9	Kar	9.3	39.5	16.9	56.4
47	Co-7	1953	Pureline selection from Cuddaph	TN	11.0	31.1	25.4	56.5
48	KMR-204	2012	GPU-26 x GE-1409	Kar	12.0	29.5	26.3	55.8
49	GPU-76			Kar	9.4	38.7	17.1	55.8
50	Co-9	1970	EC-4336 x PLR-1	TN	10.3	38.3	16.9	55.2
51	GPU-67	2009	Selection from GE-5331	Kar	11.4	28.4	26.0	54.4
52	JWM-1(Old)				11.5	28.4	25.9	54.3
53	GPU-26	1997	Indaf-5 x Indaf-9 x IE-1012	Kar	11.3	28.3	25.0	53.3
54	VL-146	1995	VL-201 x IE-882	UK	10.2	30.8	20.3	51.1
55	Hasiru Dundaga ragi*			Kar	10.6	17.6	33.2	50.8
56	GPU-45	2001	GPU-26 x L-5	Kar	10.5	26.5	23.9	50.4
57	GPU-48	2005	GPU-26 x L-5	Kar	8.9	35.2	14.7	49.9
58	Hamsa	1967	Pureline selection	Kar	11.0	24.1	19.4	43.5
59	BM-2	1995	Pure line selection	Bihar	11.3	19.8	23.2	43.0
60	HR-374	1975	EC-4840 x IE-927	Kar	11.5	24.6	17.7	42.3
61	GN-5	2009	Pure line selection	Gujarath	11.5	24.7	17.5	42.2
62	Sharada	1971	Pureline selection	AP	11.2	19.9	22.2	42.1
63	CO-11	1982	Pureline selection from MS-2584	TN	11.0	26.4	19.0	45.4
64	HPB-7-6	1976	Hamsa x Poorna	Kar	10.3	17.8	23.8	41.6
65	VL-330			UK	11.4	13.2	27.6	40.8
66	MR-2	1994	Indaf-5 x PR-202	Kar	10.5	16.8	23.0	39.8
67	Bonda ragi*			Kar	10.6	15.9	23.4	39.3
68	VL-324	2006	VL-162 x IE-3808	UK	11.5	22.1	17.1	39.2
69	Srichaithanya	2009	GPU-26 x L-5	AP	10.6	17.6	21.5	39.1
70	OUAT-1			Odisha	10.9	16.0	22.9	38.9
71	Bili kaddi ragi*			Kar	10.8	14.5	24.0	38.5
72	Nilachal	1985	Mutant of IE-642	Odisha	10.6	15.0	20.9	35.9
73	Indaf-15	1991	IE-67 X IE-927	Kar	10.7	14.8	20.7	35.5
74	GPU-75			Kar	11.4	16.3	19.2	35.5
75	Hejje ragi*			Kar	9.4	13.8	17.6	31.4
76	PRM-901			UK	10.9	15.3	16.0	31.3
77	VL-315	2004	SDFM-69 x VL-231	UK	8.9	14.8	14.7	29.5
78	VL-351			UK	11.4	9.7	17.9	27.6
79	JWM-1(new)				11.1	12.9	13.4	26.3
80	GN-1	1976	Pureline selection	Gujarath	9.8	10.6	15.3	25.9
81	KOPN-933			MR	9.5	12.2	11.3	23.5
82	Indaf-11			Kar	11.0	4.4	17.1	21.5
83	Jenu Bonda ragi*			Kar	10.7	6.8	11.5	18.3
84	PRM-802			UK	11.0	6.0	11.5	17.5
85	Pichakaddi ragi*			Kar	10.6	7.9	8.7	16.6
	Mean				10.7	31.8	22.3	54.1
	SEM±					1.9	1.4	2.9
	CD (P < 0.05)					5.4	3.9	8.1
	C.V. (%)					14.4	17.0	9.4

*: Land races, Kar: Karnataka, AP: Andhra Pradesh, TN: Tamil Nadu, UK: Uttara Khand, MR: Maharastra, UP: Uttara Pradesh. `

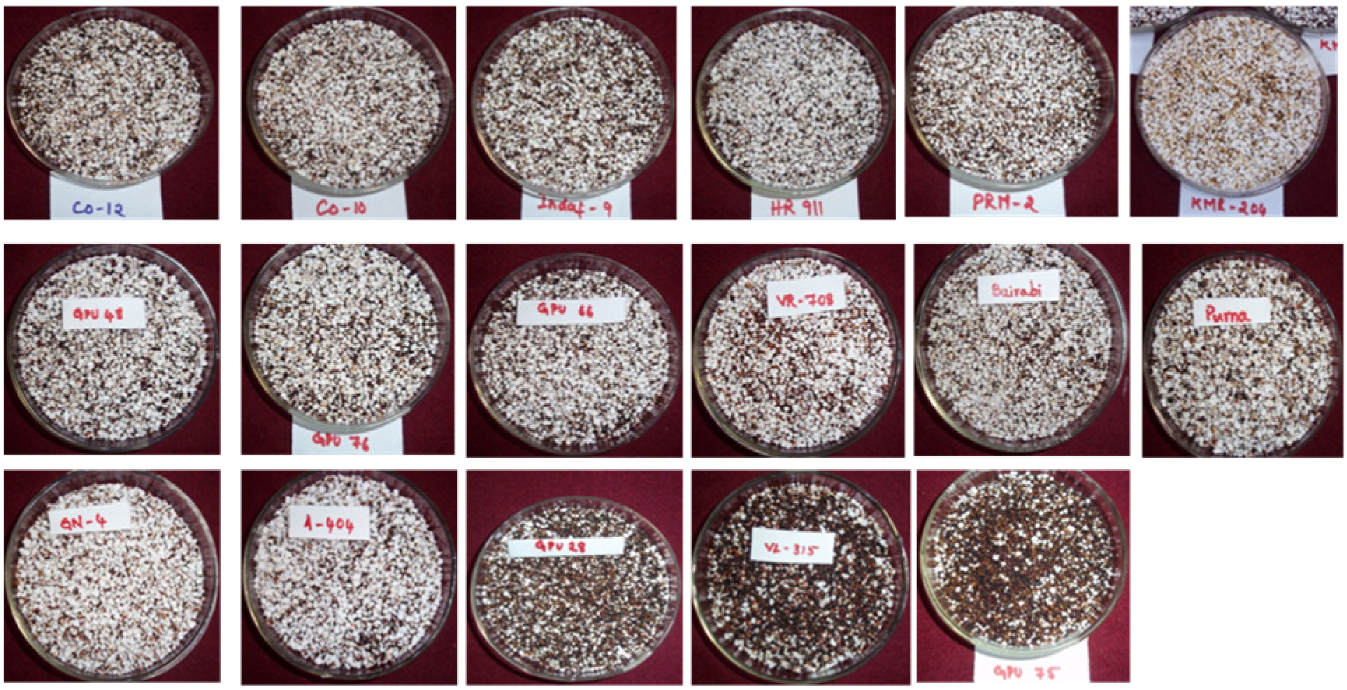

Figure 1: Contrasting finger millet varieties for popping performance

content on popping quality was studied. The initial grain moisture content was measured and used to calculate the adjusted moisture content (19%). The initial grain moisture content ranged from 8.2 (Cv. Purna) to 12.4% (Cv. Shakti), with a mean of 10.7% (Table 1). Varieties possessing 8 to 10% initial moisture content showed less than 50% popping, 10 to 12% moisture content showed a wide range from 18.6 to 88.2% popping and moisture content with >12.0% showed a popping percent of 55.8 to 67.8% (Table 1). However, no significant relationship was observed between initial grain moisture content and popping percent (Figure 2). These results infer that the general grain storage moisture content (8–10%) does not influence the popping performance of finger millet and hence, irrespective of the grain moisture content under storage, the grain should be equilibrated to 19% moisture as preconditioning during the start of popping process for achieving the maximum popping (Malleshi and Desikachar, 1981).

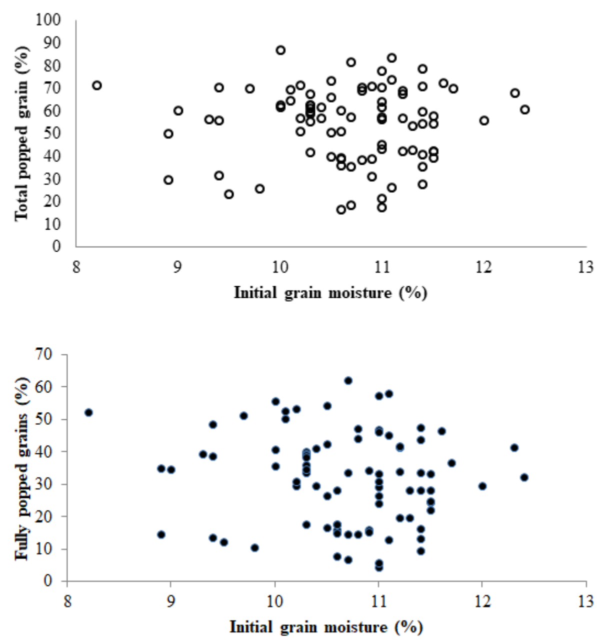

Figure 2: Relationship between initial grain moisture content and popping percent

Influence of Seed Coat Color on Popping Performance

Among 85 genotypes, most of the brown grains showed a higher popping percent as compared to the white grain genotypes like Co-9 (55.2%), Hamsa (43.5%), GN-5 (42.2%), OUAT-1 (38.9%), PRM-901 (31.3%), JWM-1 (26.3%), Indaf-11 (21.5%), and PRM-802 (17.5%; Table 1). Shukla *et al.* (1986) had reported that the brown grain varieties have a higher popping percentage (>90%) as compared to the white grain varieties (≤ 66%). Mirza *et al.* (2015) also reported that the reddish-brown seeds had relatively higher popping percent and popping volume when compared to yellow or white grain. However, Sneha *et al.* (2018) reported a high popping percentage of 68 to 84% in new and only three genotypes of white ragi. Hence, the popping could be genotype-dependent based on grain composition rather than grain color alone.

Influence of Grain Storage on Popping

Grain stored for three years showed a decrease in the popping quality, and it was genotype-dependent. For

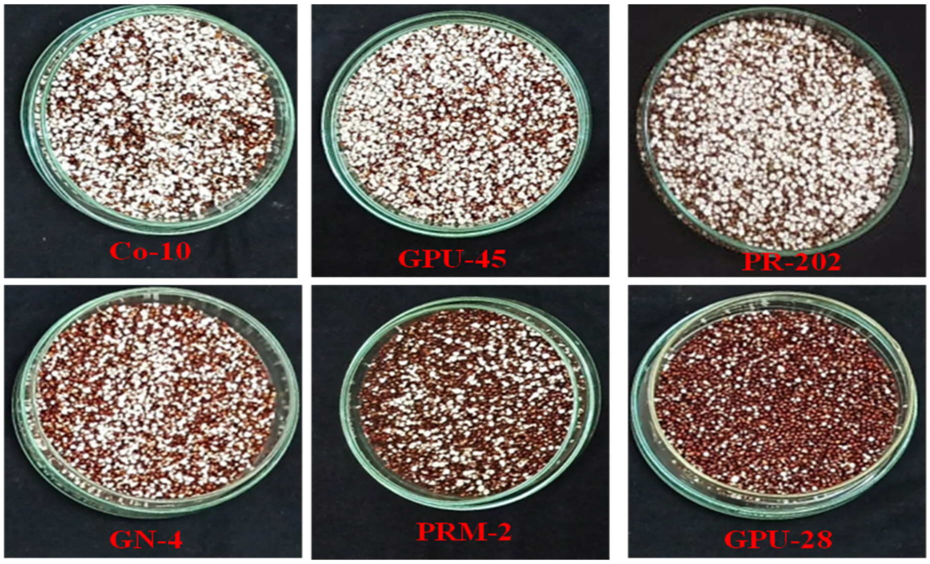

Figure 3: Genotypic variation in popping performance of three years old grains of finger millet

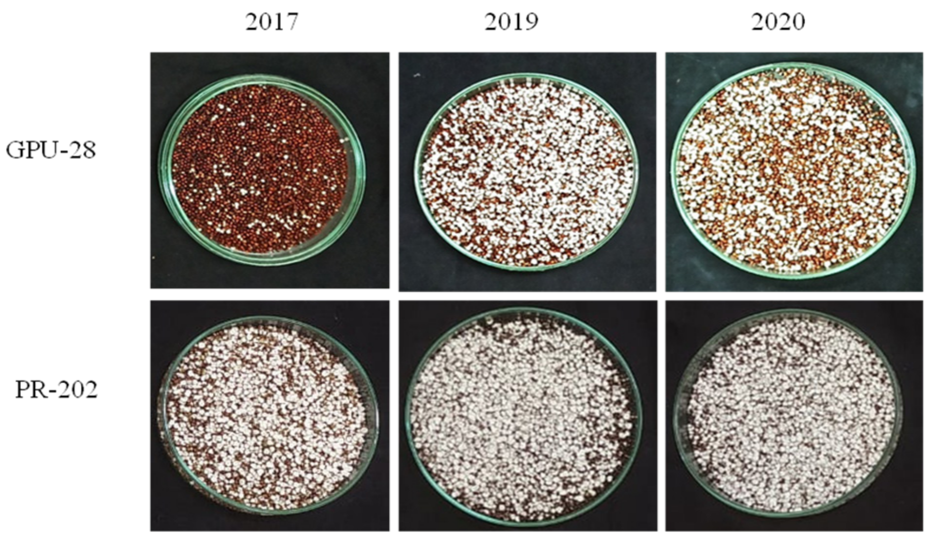

Figure 4: Effect of storage period on popping performance in cv. GPU-28 and PR-202 (2020, 2019 and 2017 are fresh, one and three years old grains, respectively)

instance, even after three-year storage, genotypes Co-10, GPU-45 and PR-202 had better-popping quality when compared to GN-4, PRM-2 and GPU-28 (Figure 3). Further, the recently harvested grains have shown a higher popping quality when compared to grain stored for three years (Figure 4). Therefore, freshly harvested grain is appropriate for popping, and the popping quality is not related to the grain moisture content as grain moisture will be equilibrated to 19% at the time of the popping process.

Conclusion

The present study evaluated a large number of genotypes (85) for popping quality and infers that stored grain moisture content does not limit the popping quality. The grain moisture content needs to be equilibrated to 19% while processing. The freshly harvested grains were found to be better for higher popping quality. The finger millet genotypes with higher popping (>65%) are Co-10, Indaf-3, *Karikaddi ragi*, PR-202, Purna, GN-4, ES-1 and PRM-2, can be exploited at the industrial level.

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