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Regional Effect on Nutritional Quality of Sorghum Hybrid Genotypes

U.D. Chavan*, S.T. Kajjdoni, M.S. Shinde, U.S. Dalvi, S.V. Nirmal, V.R. Patil, V.R. Awari, G.H. Pawar and A.S. Jadhav

All India Coordinated Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Ahmednagar (MS), India
**Corresponding author*

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A B S T R A C T

Sorghum is a staple food of most of the aired zone area people. Therefore, at all India level coordinated research programme was planned for development of hybrid sorghum genotypes having high yield and good nutritional quality parameters and these selected genotypes were grown at Rahuri and Dharwad center during Rabi-2016-17 for the study. All parameters were studied using standard methods. Considering the flour, dough, *roti* and nutritional quality parameters among the new sorghum genotypes from Rahuri center SPH 1864, CSH 13, SPH 1872, SPH 1834, SPH 1867 and from Dharwad center SPH 1865, SPH 1867, SPH 1863, SPH 1864 and CSH 15R were found promising. The new hybrid genotype SPH 1864 and SPH 1867 showed good performance at both research centers. Therefore, these hybrid genotypes should be considered for further research programme and development of new hybrid sorghum genotypes.

Introduction

In India sorghum is traditionally consumed in the form of unleavened pan cake/Roti/Bhakari. Because of sorghum is a staple food in many parts of the country. Though sorghum grains are nutritious, the consumption of this cereal is decreasing due to non-availability of easy cooking raw materials from the sorghum. The other major reasons are; dying traditional food habits, requirement of special skill for preparing sorghum rotis. For many years sorghum eating population particularly in rabi growing areas, the roti made from Maldandi (M 35-1) is preferred for taste and softness, over other genotypes. But now days some new genotypes of rabi sorghum are developed which gives better nutritional as well as organoleptic quality of the roti than the M 35-1.

Grain sorghum [*Sorghum bicolor* (L.) Moench] is an important food crop particularly in arid and semi-arid tropics. It is a dual-purpose crop providing staple food for human consumption (35%) and rest of as a fodder for livestock, alcohol production, as well as preparation of industrial products (Awika and Rooney, 2004). Many millions of people in Africa and Asia depend on sorghum as the stuff of life. Being a drought-tolerant

crop, it can give dependable and stable yields in both *kharif* (rainy) and *rabi* (post rainy) seasons. It thrives with less rainfall than is needed for rice and maize and can be grown where no other major cereal can be grown. Altogether, sorghum is one of several really indispensable crops required for the survival of man. In India, sorghum is mainly consumed in the form of unleavened pancake (*bhakri/roti*). However, several indigenous processed foods such as *bhatwadi*, *papadi*, *and roti* are prepared and consumed in the semi-arid tropics (Rao *et al.,* 1981; Chavan *et al.,* 2016a, b, c). Besides, sorghum has large potential for its use in the fermentation industry, puffed products and in weaning foods for the children of developing countries. According to an FAO (2005) report, sorghum was grown globally on an area of about 46 millions ha with a production of about 60 million tons. However in India, sorghum is cultivated on an area about 9.10 million ha with a production of 7.65 million tons (Anon 2006a, b). Sorghum grains are important source of dietary proteins, carbohydrates, minerals and B group vitamins particularly to the vegetarian diets in India (Salunkhe *et al.,* 1984; Chavan and Salunkhe, 1984; Chavan *et al.,* 1989; Chavan and Patil, 2010; Chavan *et al.,* 2015).

There is a considerable variation in sorghum for levels of protein, lysine, lipids, carbohydrates, fiber, calcium, phosphorus, iron, thiamine, and niacin, all these parameters imparts sorghum grain quality (Hulse, 1980; Bankar *et al.,* 1986; Klopfenstein and Hoseney, 1995). Post rainy season (*rabi*) sorghum is known for its quality due to which is mostly preferred for human consumption by the masses and are characterized by lustrous, pearly white, attractive grains. Developing genotypes with high yield potential coupled with nutritionally superior quality grains is the prime objective of the breeding programme.

In India sorghum is traditionally consumed in the form of unleavened pan cake/Roti/Bhakari. Because of sorghum is a staple food in many parts of the country. Though sorghum grains are nutritious, the consumption of this cereal is decreasing due to non-availability of easy cooking raw materials from the sorghum. The other major reasons are; dying traditional food habits, requirement of special skill for preparing sorghum rotis. For many years sorghum eating population particularly in rabi growing areas, the roti made from Maldandi (M 35-1) is preferred for taste and softness, over other genotypes. But now days some new genotypes of *rabi* sorghum are developed which gives better nutritional as well as organoleptic quality of the *roti* than the M 35-1. This paper deals with the details of nutritional quality of hybrid grain sorghum (post rainy season) genotypes developed through a systematic breeding programme and compared with traditional local checks.

Materials and Methods

Materials: Sorghum grains

Newly developed sorghum grain samples from initial advanced hybrid trials (IAHT) were collected from all India Co-ordinated Sorghum Improvement Project, Rahuri, Maharashtra and Dharwad, Karnataka, India during *Rabi*-2016-17 season for flour, dough, grain, *roti* and nutritional quality evaluation and further prospective.

Methods: Cleaning sorghum grains

The sorghum grains were cleaned to remove all extraneous material and damaged grains.

Milling of sorghum grains

Cleaned sorghum grains were subjected to milling in laboratory grinding mill. Whole

sorghum flour was used for nutritional quality parameters testing and preparation of *roti* product.

Physical parameters

The physical parameters such as hectoliter weight (kg/hl), water absorption of flour (%), Kneading quality (Scale 1-3), Spreading quality (Scale 1-3), water required for dough (%) were estimated by standard methods of AOAC, (1990).

Nutritional quality of sorghum grain

The sorghum grain flour was then analyzed for crude protein, total sugars, soluble protein, and free amino acids and phenolics contents using standard procedure of AOAC, (1990).

Preparation of sorghum roti

The flour was made from milling grains and fine flour was made in to dough with water. The 100 g sorghum flour was taken for preparation of *roti.* The dough was well kneaded, divided into small balls, flattened on a hard wooden or metal surface sprinkled with a small quantity of flour and was baked on both sides on a hot pan (Shobha *et al.,* 2008). The prepared *rotis* were then kept in bamboo basket covered with cloth piece and stored at room temperature for studying the extension of shelf life.

Sensory evaluation of sorghum roti

The sensory evaluation for different quality parameters like colour and appearance, flavour, texture, taste and overall acceptability was carried out immediately after preparation of *roties* at room temperature by semi trained panel of 10 judges on a 9 point hedonic scale (Amerine *et al.*, 1980). The storage study was carried out and weight loss measured at every 4, 8, 12 and 24 h.

Statistical analysis

All results obtained in the present study were analysed using standard methods of Panse and Sukatme (1967).

Results and Discussion

Total sixteen initial advanced hybrid sorghum genotypes were compared with local check genotype. The physical and nutritional parameters were evaluated using standard methods for judging the superiority of the hybrid genotype for further improvement in sorghum. The results on flour, dough, *roti* and nutritional quality are presented in Tables 1–4.

Nutritional quality

Hectoliter weight

The hectoliter weight gives the soundness of the grain as well as higher recovery of the flour. It is a unit weight of the grain in a specific volume. The hectoliter weight ranged from 68.30 to 78.70 kg/hl for Rahuri centers' genotypes while 75.40 to 81.70 for Dharwad centers' genotypes respectively. The SPH 1834 hybrid genotype gave higher hectoliter weight than rest of the genotypes studied at both centers (Tables 1 and 3). Similar results are recorded by Chavan *et al.,* (2016d, e).

Water absorption capacity

The water absorption capacity is positively correlated to the *roti* quality. The higher the water absorption capacity the superior was the quality of the *roti* due to keep the *roti* smooth and soft for longer time. Staling effect will be extended for longer time and it will remain fit for consumption. The water absorption capacity of flour ranged from 60 to 100% for Rahuri centers hybrid genotypes and 80 to 110 for Dharwad centers hybrid genotypes.

Table.1 Nutritional constituents responsible for *roti* quality prepared from different *Rabi*-2016-2017 (IAHT) cultivars of sorghum (Rahuri Center)

Genotype	Colour of the grain	Appearance/ Shape of the grain	Hectoliter weight (Kg/hl)	Water absorption (ml/100 g)	Crude Protein (%)	Soluble proteins (%)	Total sugars (%)	Starch (%)	Free amino acids (mg/100g)	Phenolics (%)
SPH 1871	CW	O	76.83	90	9.72	1.42	1.71	51.86	70.53	2.15
SPH 1868	CW	O	76.38	73	10.50	2.03	2.12	55.82	69.03	2.91
SPH 1872	CW	O	72.69	80	10.10	1.55	1.63	42.94	61.16	2.15
SPH 1870	CW	O	75.17	76	9.40	1.52	1.64	50.37	81.57	2.23
SPH 1867	CW	O	77.76	60	10.98	1.53	2.08	45.61	84.73	2.78
SPH 1801	CW	O	78.70	88	10.60	1.47	2.00	46.48	81.46	2.59
SPH 1866	CW	O	77.08	64	9.18	1.45	1.78	52.19	81.57	2.02
CSH 13	CW	O	76.31	100	9.86	1.98	1.98	43.66	70.03	2.39
SPH 1864	CW	O	76.60	86	9.60	1.51	1.94	54.15	86.38	2.52
SPH 1865	CW	O	77.40	60	10.35	1.39	1.83	50.18	90.73	2.60
CSH 15R	CW-	O	76.10	70	10.67	1.21	1.91	50.76	85.89	2.58
SPH 1863	CW	O	77.04	74	10.87	1.22	1.99	48.31	89.22	2.53
SPH 1869	CW	O	76.19	80	10.67	1.65	2.05	57.12	71.97	3.12
SPH 1837	CW	O	76.99	80	10.32	0.90	1.83	51.61	82.97	1.72
SPH 1834	CW	O	76.24	72	9.22	1.64	1.60	49.21	65.60	2.06
Phule Vasudha	CW	O	77.51	74	10.12	1.75	2.11	54.55	71.51	2.50
Range	-	-	68.30-78.70	60-100	9.18-10.98	0.90-2.03	1.63-2.57	42.94-57.12	61.16 - 90.73	1.50 - 2.91
Mean	-	-	76.08	77.00	10.02	1.54	1.93	50.35	74.83	2.37
S.E. ±	-	-	2.30	10.31	0.71	0.28	1.92	3.90	14.56	0.40
C.D. at 5 %	-	-	6.91	30.94	2.13	0.86	5.78	11.70	43.68	1.21

Replications: 3; - = No sufficient seed.
Grain colour: Creamy = C, Creamy White = CW, Dull White = DW, White = W, Brown = B, and Dull Black = DB.
Grain Shape: Round = R, Oval/Oblong = O and Wrinkle = W.

Table.2 Organoleptic quality of *roti* prepared from different hybrid/varieties of *Rabi*-2016-2017 (IAHT) cultivars of sorghum (Rahuri Center)

Genotype	Water required for dough (ml)	Kneading quality	Spreading quality	Organoleptic quality parameters					Rank by DMRT	Loss in weight during storage (%)		
				Colour & appearance	Texture	Flavour	Taste	Overall acceptability		4 hrs	8 hrs	24 hrs
SPH 1871	100	1	1	6.00	6.20	6.00	6.00	6.05	**13**	2.68	4.74	10.21
SPH 1868	80	1	1	6.20	6.00	5.80	6.20	6.05	**13**	2.28	4.81	10.24
SPH 1872	90	1	1	7.40	7.20	7.20	7.00	7.20	**3**	2.65	4.43	10.60
SPH 1870	85	1	1	6.80	6.40	6.60	6.80	6.65	**10**	2.35	4.26	10.86
SPH 1867	80	1	1	7.40	7.00	6.60	7.00	7.00	**5**	2.24	4.15	10.15
SPH 1801	85	1	1	6.20	6.40	5.80	6.60	6.25	**12**	2.32	4.10	10.23
SPH 1866	75	1	1	6.80	7.00	6.60	7.40	6.95	**6**	2.91	4.38	10.33
CSH 13	105	1	1	7.20	7.40	7.60	7.40	7.40	**2**	2.23	4.12	10.65
SPH 1864	90	1	1	7.60	7.60	7.40	7.60	7.55	**1**	2.15	3.83	10.57
SPH 1865	70	1	1	7.20	6.40	6.80	6.80	6.80	**9**	2.26	4.53	11.21
CSH 15R	80	1	1	6.20	6.20	6.80	7.00	6.55	**11**	2.34	4.31	10.35
SPH 1863	85	1	1	7.00	6.80	6.80	6.80	6.85	**8**	2.37	4.46	10.08
SPH 1869	90	1	1	7.00	6.80	7.00	6.80	6.90	**7**	2.53	4.86	10.71
SPH 1837	90	1	1	7.20	7.40	6.80	7.00	7.10	**4**	2.43	4.21	10.67
SPH 1834	80	1	1	7.60	6.80	6.80	7.20	7.10	**4**	2.55	4.38	10.82
Phule Vasudha	85	1	1	6.80	6.60	7.00	6.80	6.80	**9**	2.34	4.37	10.86
Range	75-105	-	-	6.00-7.60	6.00-7.60	5.80-7.60	6.00-7.60	6.05-7.55	-	2.15-2.91	3.83-4.86	10.08-11.21
Mean	86	-	-	6.88	6.72	6.72	6.87	6.80	-	2.41	4.38	10.54
S.E. ±	8	-	-	0.50	0.48	0.48	0.40	0.42	-	0.18	0.25	0.30
C.D. at 5 %	25	-	-	1.51	1.46	1.44	1.22	1.27	-	0.57	0.78	0.90

Replications: 5 minimum; - = No sufficient seed.

Kneading quality of dough, score: Good = 1, Fair = 2, Poor = 3. Spreading quality of *roti*, score: Easy spreading without crack = 1, Slightly difficult to spread with minute cracks = 2, Difficult to spread with cracks = 3.

Sensory score: Like extremely (Excellent) - 9, Like very much (Very good) - 8, Like moderately - 7, Like slightly-6, Neither like nor dislike - 5, Dislikes lightly - 4, Dislike moderately - 3, Dislike very much - 2, Dislike extremely-1.

Table.3 Nutritional constituents responsible for *roti* quality prepared from different *Rabi*-2016-2017 (IAHT) cultivars of sorghum (Dharwad Center)

Genotype	Colour of the grain	Appearance/ Shape of the grain	Hectoliter weight (Kg/hl)	Water absorption (ml/100 g)	Crude Protein (%)	Soluble proteins (%)	Total sugars (%)	Starch (%)	Free amino acids (mg/100g)	Phenolics (%)
SPH 1871	CW	O	80.57	85	9.42	0.82	2.20	58.20	81.50	1.07
SPH 1868	CW	O	79.55	85	9.50	1.03	2.38	64.59	71.37	1.34
SPH 1872	CW	O	75.40	90	9.04	0.66	1.48	55.47	68.63	1.00
SPH 1870	CW	O	79.30	80	8.35	1.17	2.05	60.68	79.19	0.93
SPH 1867	CW	O	81.04	100	11.06	1.05	2.53	51.07	79.60	1.58
SPH 1801	CW	O	81.22	90	9.19	1.21	2.20	54.44	78.83	1.46
SPH 1866	CW	O	80.71	90	9.48	1.15	2.27	56.61	82.34	1.54
CSH 13	CW	O	80.04	110	9.75	0.53	2.23	54.53	80.20	0.42
SPH 1864	CW	O	80.15	100	9.32	1.08	2.17	56.51	84.64	1.52
SPH 1865	CW	O	81.08	100	10.13	1.10	2.51	56.27	85.72	1.68
CSH 15R	CW-	O	80.58	90	9.19	1.29	2.34	58.57	77.77	1.47
SPH 1863	CW	O	80.71	100	8.67	0.91	1.97	55.50	84.96	1.35
SPH 1869	CW	O	80.29	90	8.74	1.16	2.09	60.01	64.28	1.59
SPH 1837	CW	O	81.37	90	9.12	1.08	1.94	52.41	73.99	1.32
SPH 1834	CW	O	81.70	100	9.02	1.05	1.73	52.91	71.41	1.29
Local Check	CW	O	79.90	90	9.16	1.20	2.35	65.27	78.11	1.35
Range	-	-	75.40-81.70	80- 110	8.35-11.06	0.53-1.29	1.48-2.53	51.07-65.27	64.28-85.72	0.42-1.68
Mean	-	-	80.23	92.81	9.32	1.03	2.15	57.07	77.66	1.31
S.E. ±	-	-	1.39	7.85	0.60	0.19	0.26	3.90	5.97	0.30
C.D. at 5 %	-	-	4.20	23.56	1.82	0.60	0.80	11.71	17.91	0.93

Replications: 3; - = No sufficient seed.
Grain colour: Creamy = C, Creamy White = CW, Dull White = DW, White = W, Brown = B, and Dull Black = DB.
Grain Shape: Round = R, Oval/Oblong = O and Wrinkle = W.

Table.4 Organoleptic quality of *roti* prepared from different hybrid/varieties of *Rabi*-2016-2017 (IAHT) cultivars of sorghum (Dharwad Center)

Genotype	Water required for dough (ml)	Kneading quality	Spreading quality	Organoleptic quality parameters					Rank by DMRT	Loss in weight during storage (%)		
				Colour & appearance	Texture	Flavour	Taste	Overall acceptability		4 hrs	8 hrs	24 hrs
SPH 1871	95	1	1	7.60	7.00	7.40	6.80	7.20	**11**	2.33	4.86	10.71
SPH 1868	98	1	1	7.20	6.80	7.00	7.20	7.05	**12**	2.13	4.21	10.67
SPH 1872	100	1	1	5.60	7.00	7.00	7.20	6.70	**14**	2.56	4.38	9.82
SPH 1870	90	1	1	6.40	6.60	7.00	7.60	6.90	**13**	2.34	4.37	10.86
SPH 1867	108	1	1	8.20	8.40	8.60	8.00	8.30	**2**	2.25	3.83	10.57
SPH 1801	100	1	1	7.80	7.60	8.00	8.00	7.85	**6**	2.26	4.53	10.31
SPH 1866	100	1	1	7.40	7.60	7.80	7.60	7.60	**9**	2.34	4.31	10.35
CSH 13	115	1	1	8.80	7.20	7.80	7.60	7.85	**6**	2.37	4.46	10.28
SPH 1864	105	1	1	8.60	7.00	8.40	8.20	8.05	**4**	2.24	4.15	10.35
SPH 1865	105	1	1	8.40	8.20	8.60	8.40	8.40	**1**	2.32	4.10	10.23
CSH 15R	100	1	1	8.40	7.60	8.20	8.00	8.05	**4**	2.81	4.38	10.33
SPH 1863	110	1	1	8.40	7.80	8.20	8.00	8.10	**3**	2.23	4.32	10.45
SPH 1869	100	1	1	8.20	7.60	7.80	7.60	7.80	**7**	2.78	4.74	10.21
SPH 1837	100	1	1	7.60	7.00	7.80	7.40	7.45	**10**	2.28	4.61	10.34
SPH 1834	105	1	1	7.80	7.80	8.00	8.20	7.95	**5**	2.65	4.43	10.40
Local Check	100	1	1	7.80	7.40	7.80	7.60	7.65	**8**	2.35	4.36	10.76
Range	90-115	-	-	5.60- 8.80	6.60-8.40	7.00-8.60	6.80-8.40	6.70- 8.40	-	2.13-2.81	3.83-4.86	9.82-10.86
Mean	101.00	-	-	7.76	7.41	7.84	7.71	7.68	-	2.39	4.38	10.42
S.E. ±	5.00	-	-	0.80	0.48	0.50	0.41	0.48	-	0.19	0.23	0.24
C.D. at 5 %	17.00	-	-	2.42	1.46	1.52	1.25	1.45	-	0.58	0.72	0.74

Replications: 5 minimum; - = No sufficient seed.

Kneading quality of dough, score: Good = 1, Fair = 2, Poor = 3. Spreading quality of *roti*, score: Easy spreading without crack = 1, Slightly difficult to spread with minute cracks = 2, Difficult to spread with cracks = 3.

Sensory score: Like extremely (Excellent) - 9, Like very much (Very good) - 8, Like moderately - 7, Like slightly-6, Neither like nor dislike - 5, Dislikes lightly - 4, Dislike moderately - 3, Dislike very much - 2, Dislike extremely-1.

The hybrid genotype CSH 13 gave higher water absorption percentage than other genotypes (Table 1 and 3). These results are in agreement with previous research workers such as Michniewicz *et al.,* (1991) and Chavan *et al.,* (2016d, e).

Crude protein

The crude protein content ranged from 9.18% (SPH 1866) to 10.98% (SPH 1867) in the initial advanced hybrid genotypes studied with their checks at Rahuri center. The protein content ranged from 8.35% (SPH 1870) to 11.06% (SPH 1867) at Dharwad center (Tables 1 and 3).

The genotype SPH 1867 hybrid gave highest protein content among the genotypes studied at both centers. Higher protein content is a good character for nutritional value of that genotype and also for human nutrition. These results are in agreement with previous research workers such as Michniewicz *et al.,* (1991) and Chavan *et al.,* (2016d, e).

Soluble protein

The soluble protein content in the flour mostly responsible for the holding more water and developing smoothness to the *roti*. While cooking soluble proteins, carbohydrates and free amino acids take part in the various reactions and develop specific aroma to the *roti*.

The soluble protein content in the flour ranged from 0.90% (SPH 1837) to 2.03% (SPH 1868) at Rahuri center trials while soluble protein ranged from 0.53 (CSH 13) to 1.29% (CSH 15R) at Dharwad center trials. All the genotypes were significantly different in their soluble content. These results are in agreement with previous research workers such as Michniewicz *et al.,* (1991) and Chavan *et al.,* (2016d, e).

Total soluble sugars

At Rahuri trials the total soluble sugars in hybrid genotypes ranged from 1.63% (SPH 1872) to 2.12% (SPH 1868). At Dharwad trials total sugar content ranged from 1.48 (SPH 1872) to 2.53% (SPH 1867). All the hybrid genotypes studied were significantly different. The higher sugar percentage in sorghum flour representing good amylolyptic activity while preparation of *roti*. Total soluble sugars are mostly responsible for good taste of the *roti* (Tables 1 and 3). These results are similar to Chavan *et al.,* (2016d, e).

Starch

The starch content of the initial advanced hybrid genotypes ranged from 42.94% (SPH 1872) to 57.12% (SPH 1869) at Rahuri center. At Dharwad center starch ranged from 51.07% (SPH 1867) to 65.27% (Local check). Higher starch content gives good colour and amylopetic activity during *roti* preparation. *Roti* remain soft for longer time and increase self-life. Similar results are reported by Vietor *et al.,* (1992) and Nandini and Salimath (2001).

Free amino acids

The free amino acids in the studied genotypes at Rahuri trials ranged from 61.16 mg/100g flour (SPH 1872) to 90.73 mg/100g flour (SPH 1865). At Dharwad center trials free amino acids ranged from 64.28 mg/100g flour (SPH 1869) to 85.72 mg/100g flour (SPH 1865). The initial and initial advanced hybrid sorghum genotypes were significantly different in the free amino acid content. This component mostly responsible for aroma development while roasting combines with moisture, soluble proteins and sugars. These results are in agreement with previous research workers such as Michniewicz *et al.,* (1991) and Chavan *et al.,* (2016d, e).

Phenolics

The phenolics content in the studied hybrid genotypes at Rahuri center trials ranged from 1.72% (SPH 1837) to 2.91% (SPH 1868). At Dharwad trials phenolics content ranged from 0.42% (CSH 13) to 1.68% (SPH 1865). The phenolics mostly responsible for astringent taste to the product but nowadays it acts as antioxidants which prevent cancer development in human body. These nutritional quality parameters results are in agreement with Glover *et al.,* (186), Chavan *et al.,* (1988), Chavan *et al.,* (2009), Chavan and Patil (2010).

Roti quality

All sorghum grain samples of initial advanced hybrid trials of *Rabi*-2016-17 season grown at Rahuri and Dharwad centers were used for the *roti* preparation and then used for organoleptic evaluation (colour and appearance, texture, falvour/aroma, taste and overall acceptability using 1 to 9 hedonic scale rating (Tables 2 and 4). On the basis of these parameters and overall acceptability Duncan Multiple Range Taste was used to give the numbering for ranking the hybrid genotypes. For smoothness of the *roti* storage study was also conducted and water loss (weight loss of *roti*) was measured at 4, 8 and 24 hrs. The results regarding weight loss in *roti* are presented in Table 2 and 4. These results are in accordance with the previous research work done by Murty and Subramanian (1981), Subramanian and Jambunathan (1981; 1982), Salunkhe *et al.*, (1984) and Shobha *et al.*, (2008).

Considering the flour, dough, *roti* and nutritional quality parameters among the new hybrid sorghum genotypes from Rahuri center SPH 1864, CSH 13, SPH 1872, SPH 1834, SPH 1867 and from Dharwad center SPH 1865, SPH 1867, SPH 1863, SPH 1864 and CSH 15R were found promising. At both research centers SPH 1864 and SPH 1867 hybrid genotypes showed good performance without any adverse effect of region. Therefore, these genotypes should be considered for further research programme and development of new hybrid sorghum genotypes.

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