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RESEARCH ARTICLE

EVALUATION OF NEW *KHARIF* SORGHUM GENOTYPES FOR FLOUR, DOUGH, *ROTI* AND NUTRITIONAL QUALITY

***Chavan, U. D., Lande, S. B., Kotecha, P. M. and Nirmal, S. V.**

Department of Food Science and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, India

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ABSTRACT

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. During Kharif-2017 (Dharwad Center) total 28 sorghum genotypes from advance varietal trials (AVT; 18) and advance hybrid trials (AHT; 10) were evaluated for flour, dough, roti and nutritional quality parameters using above parameters. On the basis of these characters among the new sorghum genotypes from AVT; DSV 4, SPV 2437, CSV 27 and SPV 2424 and from AHT; CSH 16, CSH 25 and SPH 1846 were found promising for flour, dough, *roti* and nutritional quality.

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INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is the king of cereals and is one of the important food crops in dry lands of tropical Africa, India and China (Shobha *et al.,* 2008). India ranks second in the world for sorghum production and first with respect to many regionally important crops like millets and pseudo-cereals. Sorghum is the principal staple food of Maharashtra, and is also an important food of Karnataka, Madhya Pradesh, Tamil Nadu and Andhra Pradesh. Sorghum can be milled to produce starch or grits (semolina) from which many ethnic and traditional dishes can be made. The most common products are leavened and unleavened breads, porridges, boiled grains and steam cooked products such as couscous. Sorghum flour also makes an excellent fry coating for fish, chicken and beef. Sorghum is also used in the preparation of several snacks and for popping, chewing, and malting (Rao and Murty, 1981). There is a considerable variation in sorghum for levels of proteins, lysine, lipids, carbohydrates, fiber, calcium, phosphorus, iron, thiamine, and niacin (Chavan *et al.,* 2009).

Corresponding author: **Chavan, U. D.,**
Department of Food Science and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri, India
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Sorghum has chemical composition similar to or better than rice and wheat in some respects. The grains contain high fiber and non-starchy polysaccharides and starch with some unique characteristics. Protein quality and essential amino acid profile of sorghum is better than many of the cereals. Sorghum in general is rich source of B-complex vitamins (Chavan *et al*., 1988; 2010; 2015, 2017a-d). Sorghum *roti* is very popular in villages and small towns as an accompaniment to gravy meat and vegetable curries and is one of the traditional recipes of India. It is round, flat, unleavened bread often used in the cuisine of western and central India, especially in the states of Gujarat, Sorghum *roti* is known by various names in the different languages of India: *chapati* (Hindi), *bhakri* (Marathi), *rotla* (Gujarati), *rotte* (Telugu), etc. (Subramanian and Jambunathan, 1981). Because sorghum flour is gluten-free flour, it is very tough to spread the dough without breaking the shape and one really needs hands-on experience and many failed attempts to get the skill. No leavening agents, oil/ghee are added. Just fresh sorghum flour, warm water and touch of fire - pure grain power in its glory. Arabinoxylans have been isolated from different cereals and responsible to play important role in maintaining water balance and rheological properties of dough (Michniewicz *et al.,* 1991; Vietor *et al.,* 1992; Nandini *et al.,* 2001). Typically *bhakri* is accompanied by various curries, chutney (*thecha* – a thick paste of really hot green or red chilies) and raw onion (Murty and Subramanian,

1981). *Bhakri* has its own advantages from dietary point of view. Being made from cereals, it is high in dietary fiber but at the same time very easy to digest (Chavan *et al*., 1989, 2010; Nirmal *et al*., 2017 and Chavan and Salunkhe, 1984**).** However it was necessary to study the effect different locations on the nutritional and roti quality therefore, present study was under taken to identify superior genotype for future development.

MATERIAL AND METHODS

Material: Sorghum grains: Sorghum grains were obtained from two locations Dharwad and Udaipur for nutritional and roti quality testing. These sorghum grain samples were collected during *Kharif*-2017 season.

***Methods: Cleaning sorghum grains*:** The sorghum grains were cleaned to remove all extraneous material.

***Milling of sorghum grains*:** Cleaned sorghum grains were subjected to milling in laboratory grinding mill using 60 mesh sieve. Whole sorghum flour was used for nutritional quality parameters testing and preparation of *roti* product.

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 A.O.A.C., (1990).

Preparation of sorghum roti: The flour was made from milling grains, sieved 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 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 after every 4, 8, 12 and 24 h by semi trained panel of 10 judges on a 9 point hedonic scale (Amerine *et al.*, 1980).

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

RESULTS AND DISCUSSION

Nutritional quality: Total fourteen advanced sorghum genotypes were compared with local check genotype for nutritional quality and roti quality. The results on flour, dough, *roti* and nutritional quality are presented in Tables 1 to 4.

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 71.16 to 81.54 kg/hl for AVT and 74.26 to 80.76 for AHT trials respectively. The kharif AVT entry DSV 4 gave higher hectoliter weight than rest of the genotypes studied in AVT and AHT trials (Tables 1 and 3).

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*. The water absorption capacity of flour ranged from 75 to 95% for AVT and 75 to 95 for AHT trials. The genotype CSV 27 and SPH 1846 gave higher water absorption percentage than other genotypes.

Crude protein: The crude protein content ranged from 8.67% (SPV 2438) to 11.47% (DSV 4) in the advanced varietal genotypes studied with their checks. In AHT protein content ranged from 8.38% (CSH 30) to 12.21% (CSH 16) (Tables 1 and 3).

Soluble protein: The soluble protein content in the flour mostly responsible for the holding more water and developing smoothness to the *roti*. The soluble protein content in the flour ranged from 0.16% [CSV 17] to 0.79% [SPV 2424) in AVT trials. In AHT soluble protein ranged from 0.12 (SPH 1817) to 0.55% CSH 16). All the genotypes were significantly different in their soluble content (Tables 1 and 3). The relationship between the physiochemical characters and roti quality indicated that quantity of water-soluble protein; soluble sugars and amylose jointly influence the roti quality similar results were reported by Subramanian and Jambunathan (1982).

***Total soluble sugars*:** In AVT trials the total soluble sugars ranged from 1.38% (CSV 17) to 2.25% (SPV 2366). In AHT total sugar content ranged from 1.37 (DSH 6) to 2.13% (CSH 16). The change in the sugar accumulation in the sorghum genotype may be due to genetic makeup and location as well as soil and climate effect. All the genotypes studied were significantly different. The higher sugar percentage in sorghum flour representing good amylolyptic activity while preparation of *roti*. Higher level of sugars present in the sorghum flour holds more water and makes *roti* softer. Total soluble sugars are mostly responsible for good taste of the *roti* (Tables 1 and 3).

Starch: The starch content of the advanced varietal genotypes ranged from 41.90% (SPV 2301) to 58.44% (SPV 2366). In AHT starch ranged from 43.76% (SPH 1850) to 56.06% (SPH 1820). Amylose and amylopectin components of the starch play major role during cooking of *roti* and development of good flavor to the sorghum *roti*. Higher starch content gives good colour and amylopetic activity during *roti* preparation.

Free amino acids: The free amino acids in the studied genotypes of AVT trials ranged from 73.08 mg/100g flour (CSV 17) to 85.17 mg/100g flour (SPV 2364). In AHT trials free amino acids ranged from 58.13 mg/100g flour (DSH 6) to 79.71 mg/100g flour (SPH 1816). The advanced 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.

Phenolics: The phenolics content in the studied genotypes of AVT trials ranged from 0.75% (SPV 2366) to 1.74% (CSV 17). In AHT trials phenolics content ranged from 1.14% (SPH 1816) to 2.28% (CSH 16). The phenolics mostly responsible for astringent taste to the product but nowadays it acts as antioxidants which prevent cancer development in human body. Therefore, its presence in the food system is a positive sign for acting as antioxidants in the food system and prevents oxidation of the food components in the human body.

Table 1. Nutritional constituents responsible for *roti* quality prepared from different genotypes of *Kharif* -2017 (AVT) cultivars of sorghum (Dharwad Center)

Genotype/ Entry code	Colour of the grain	Appearance/ Shape of the grain	Hectoliter weight (Kg/hl)	Water absorption (ml/100g)	Crude Protein (%)	Soluble proteins (%)	Total sugars (%)	Starch (%)	Free amino acids (mg/100g)	Phenolics (%)
SPV 2364	DB	RO	81.22	80	9.95	0.41	1.99	47.72	85.17	1.13
CSV 27	DB	RO	78.59	95	10.74	0.46	2.05	48.14	82.56	1.33
SPV 2301	DB	RO	80.03	90	10.29	0.42	1.47	41.90	81.54	1.36
CSV 17	DB	RO	79.16	90	9.89	0.16	1.38	46.87	73.08	1.74
SPV 2362	DB	RO	80.30	85	10.34	0.37	1.78	49.24	80.49	1.47
CSV 20	DB	RO	79.86	75	9.71	0.70	2.00	48.86	74.73	1.26
SPV 2366	DB	RO	71.16	85	8.84	0.27	2.25	58.44	78.78	0.75
SPV 2438	DB	RO	78.68	80	8.67	0.52	1.86	53.53	80.39	1.03
SPV 2423	DB	RO	78.35	80	10.08	0.79	2.21	51.52	80.35	1.46
SPV 2425	DB	RO	78.13	80	9.30	0.60	1.95	50.46	74.27	1.12
CSV 23	DB	RO	78.23	75	10.61	0.71	1.76	44.69	84.64	1.41
SPV 2358	DB	RO	77.12	80	9.43	0.24	1.66	48.70	73.22	1.65
SPV 2423	DB	RO	77.37	85	9.32	0.36	1.64	44.17	72.47	1.31
SPV 2363	DB	RO	78.72	80	10.36	0.29	1.89	47.30	84.34	1.33
SPV 2437	DB	RO	80.38	75	11.16	0.51	2.02	44.11	77.63	1.46
SPV 2433	DB	RO	78.56	85	10.06	0.36	1.86	45.27	74.32	1.75
SPV 2367	DB	RO	77.88	85	8.72	0.50	1.79	49.18	77.99	0.86
DSV 4	DB	RO	81.54	85	11.47	0.41	2.18	42.00	76.68	1.14
Range	-	-	71.16-81.54	75-95	8.67-11.47	0.16-0.79	1.38-2.25	41.90-58.44	73.08-85.17	0.75-1.74
Mean	-	-	78.63	85	9.94	0.45	1.87	47.89	78.48	1.31
S.E. ±	-	-	2.17	4.50	0.77	0.16	0.23	3.98	4.08	0.26
C.D. at 5 %	-	-	6.54	13.53	2.33	0.50	0.70	11.94	12.26	0.80

Replications: 3: 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 genotypes of *Kharif*-2017 (AVT) 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 and appearance	Flavour	Texture	Taste	Overall acceptability		4 hrs	8 hrs	24 hrs
SPV 2364	72	1	1	7.6	7.4	7.2	7.2	7.35	**9**	1.86	2.58	4.63
CSV 27	75	1	1	8.6	7.6	7.8	8.2	8.05	**2**	1.64	2.39	5.33
SPV 2301	83	1	1	8.6	7.2	7.6	8.0	7.85	**5**	1.89	2.54	5.28
CSV 17	85	1	1	8.0	7.4	8.2	7.8	7.85	**5**	2.07	3.73	5.67
SPV 2362	80	1	1	7.2	6.8	7.6	6.6	7.05	**12**	2.13	2.63	5.19
CSV 20	70	1	1	7.6	7.8	7.4	7.2	7.50	**7**	2.53	3.36	5.87
SPV 2366	81	1	1	8.2	7.2	7.6	7.2	7.55	**6**	1.90	2.94	5.73
SPV 2438	70	1	1	7.4	6.8	7.4	7.2	7.20	**11**	2.71	3.65	4.55
SPV 2423	70	1	1	8.7	7.7	7.8	8.5	8.09	**3**	2.56	3.75	4.94
SPV 2425	76	1	1	7.0	7.8	7.2	7.8	7.45	**8**	1.86	2.58	4.63
CSV 23	70	1	1	7.8	8.0	7.4	7.0	7.55	**6**	1.64	2.39	5.33
SPV 2358	75	1	1	7.6	7.0	7.4	7.2	7.30	**10**	1.89	2.54	5.28
SPV 2423	80	1	1	7.4	6.8	6.6	6.8	6.90	**13**	3.45	4.14	4.99
SPV 2363	75	1	1	8.0	8.0	8.4	7.4	7.95	**4**	1.86	2.80	4.89
SPV 2437	73	1	1	8.8	8.0	7.4	8.4	8.15	**1**	1.90	2.94	5.73
SPV 2433	80	1	1	7.6	7.2	7.2	7.2	7.30	**10**	2.71	3.65	4.55
SPV 2367	78	1	1	7.6	7.4	7.2	7.2	7.35	**9**	2.56	3.75	4.94
DSV 4	80	1	1	8.6	7.8	8.0	8.2	8.15	**1**	1.86	2.58	4.63
Range	70-85	-	-	7.0-8.8	6.8-8.0	6.6-8.4	6.6-8.5	6.90-8.15	-	1.64-3.45	2.39-4.14	4.55-5.87
Mean	76.28	-	-	7.91	7.44	7.52	7.51	7.59	**-**	2.17	3.05	5.12
S.E. ±	4.49	-	-	0.54	0.40	0.40	0.54	0.37	**-**	0.46	0.56	0.42
C.D. at 5 %	13.47	-	-	1.63	1.23	1.22	1.64	1.14	-	1.40	1.70	1.28

Replications: 5 minimum: 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 genotypes of *Kharif*-2017 (AHT) cultivars of sorghum (Dharwad Center).

Genotype/ Entry code	Colour of the grain	Appearance/ Shape of the grain	Hectoliter weight (Kg/hl)	Water absorption (ml/100g)	Crude Protein (%)	Soluble proteins (%)	Total sugars (%)	Starch (%)	Free amino acids (mg/100g)	Phenolics (%)
SPH 1817	DB	RO	79.56	76	9.65	0.12	1.45	44.83	77.72	1.67
SPH 1846	DB	RO	79.41	95	11.01	0.16	1.85	45.37	76.99	1.81
CSH 16	DB	RO	79.11	77	12.21	0.55	2.13	48.64	67.79	2.28
SPH 1850	DB	RO	80.76	85	10.83	0.43	1.84	43.76	67.98	1.58
SPH 1849	DB	RO	78.64	80	10.59	0.26	1.60	45.16	72.85	1.72
CSH 30	DB	RO	78.80	75	8.38	0.31	1.50	50.10	63.42	1.26
SPH 1820	DB	RO	77.59	75	10.22	0.29	2.06	56.06	66.09	1.38
CSH 25	DB	RO	78.42	75	11.49	0.39	2.10	51.63	75.05	1.67
SPH 1816	DB	RO	79.51	75	9.79	0.38	1.99	52.61	79.71	1.14
DSH 6	DB	RO	74.26	85	8.64	0.17	1.37	49.94	58.13	1.60
Range	-	-	74.26-80.76	75-95	8.38-12.21	0.12-0.55	1.37-2.13	43.76-56.06	58.13-79.71	1.14-2.28
Mean	-	-	78.61	79.80	10.28	0.31	1.79	48.81	70.57	1.61
S.E. $\pm$	-	-	1.65	6.32	1.14	0.12	0.27	3.80	6.64	0.30
C.D. at 5 %	-	-	4.95	18.96	3.43	0.38	0.82	11.40	19.93	0.90

Replications: 3: 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 genotypes of *Kharif*-2017 (AHT) 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 and appearance	Flavour	Texture	Taste	Overall acceptability		4 hrs	8 hrs	24 hrs
SPH 1817	70	1	1	6.6	7.6	7.4	6.8	7.10	8	2.10	2.82	4.83
SPH 1846	90	1	1	8.6	7.6	8.2	7.8	8.05	3	2.11	2.95	4.64
CSH 16	70	1	1	9.0	8.6	8.0	8.2	8.45	1	1.73	2.58	4.17
SPH 1850	80	1	1	7.6	8.2	7.8	7.2	7.70	5	2.39	3.14	5.67
SPH 1849	75	1	1	7.0	7.6	7.6	7.4	7.40	6	2.01	3.55	5.41
CSH 30	65	1	1	6.6	6.8	7.2	7.2	6.95	10	1.89	2.44	4.89
SPH 1820	65	1	1	8.0	8.4	8.0	7.4	7.95	4	1.85	2.87	4.09
CSH 25	70	1	1	8.6	8.0	8.2	8.4	8.30	2	1.35	2.12	4.36
SPH 1816	70	1	1	7.0	7.4	6.6	7.6	7.15	7	1.89	2.56	4.68
DSH 6	80	1	1	7.2	7.4	6.8	6.8	7.05	9	2.08	3.36	5.16
Range	65-90	-	-	6.6-9.0	6.8-8.6	6.6-8.2	6.8-8.4	6.95-8.45	-	1.35-2.39	2.12-3.55	4.09-5.67
Mean	73.50	-	-	7.62	7.76	7.58	7.48	7.61	-	1.94	2.84	4.79
S.E. $\pm$	7.43	-	-	0.83	0.51	0.54	0.50	0.52	-	0.26	0.41	0.49
C.D. at 5 %	22.30	-	-	2.51	1.54	1.62	1.52	1.58	-	0.79	1.24	1.47

Replications: 5 minimum
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.

Roti quality: All grain samples of AVT and AHT trials of *kharif*-2017 season grown at Dharwad center 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 genotypes. For smoothness of the *roti* storage study was also conducted and water loss was measured at 4, 8 and 24hrs. All the genotypes showed acceptable quality parameters for nutritional as well as for *roti* quality. For nutritional and *roti* quality similar results are reported by previous scientists (Subramanian and Jambhunathan, 1982; Bankar, *et al*., 1986; Glover *et al*., 1986; Klopfenstein and Hoseney, 1995; Chavan *et al*., 2015).

Conclusions

During *Kharif*-2017 (Dharwad Center) total 28 sorghum genotypes from AVT (18) and AHT (10) were evaluated for flour, dough, *roti* and nutritional quality parameters using above parameters. On the basis of these characters among the new sorghum genotypes from AVT; DSV 4, SPV 2437, CSV 27 and SPV 2424 and from AHT; CSH 16, CSH 25 and SPH 1846 were found promising for flour, dough, *roti* and nutritional quality (Tables 1 to 4).

REFERENCES

Amerine, M. A., Pangborn, R. M. and Rossler, E.B. 1980. Principles of sensory evaluation of food. *Academic Press*, New York.

AOAC, 1990. Official Methods of Analysis. 15th Edn. Association of Official Analytical Chemists, Washington, DC, pp.113-127.

Bankar, J. R., Chavan, J. K. and Kadam, S. S. 1986. Effects of Incorporation of Sorghum Flour in wheat Maida on Physical and Sensory Properties of Bread, Buns, cookies and Biscuits. *Journal Maharashtra Agriculture Universities* 11(2): 216-218.

Chavan U. D., Pansare, S. S., Patil, J. V. and Shinde, M. S. 2015. Preparation and Nutritional Quality of Sorghum *Papads*. *Int. J. Curr. Microbiol. App. Sci*., 4(5): 806-823.

Chavan, J. K. and Salunkhe, D. K. 1984. Structure of sorghum grain in nutritional and processing quality of Sorghum. *Qual. Plant. Pl. Foods Human Nutr.,* 29: pp.21-31

Chavan, J.K., Chavan, U.D. and Nagarkar, V.D. 1989. Effects of malting and fermentation on nutritional quality of sorghum. *J. Maharashtra Agric. Univ*., 14 (2) : 246-247.

Chavan, U. D. and Patil, J. V. 2010. Grain Processing of Sorghum. Ibdc publishers, Lucknow. pp. 10-15

Chavan, U. D., Kajjdoni, S. T., Shinde, M. S., Dalvi, U. S., Nirmal, S. V., Patil, V. R., Awari, V. R., Pawar, G. H. and Jadhav, A. S. 2017d. Regional Effect on Nutritional Quality of Sorghum Hybrid Genotypes. *Int.J.Curr. Microbiol. App. Sci.,* 2017 6(11): 75-85.

Chavan, U. D., Kajjdoni, S. T., Shinde, M. S., Dalvi, U. S., Nirmal, S. V., Awari, V. R., Patil, V. R., Pawar, G. H. and Jadhav, A. S. 2017c. Regional Effect on Nutritional Quality of Sorghum Genotypes. I*nt. J. Curr. Microbiol. App. Sci*., 6(10): 380-389.

Chavan, U. D., Nirmal, S. V., Gadakh, S. R., Shinde, M. S., Patil, V.R., Awari, V. R. and Dalvi, U. S. 2017b. Physiological Evaluation of Genotypes for Drought Tolerance on Receding Soil Moisture. *Int. J. Curr. Microbiol. App. Sci*., 6(6): 2174-2183.

Chavan, U. D., Patil, J. V. and Shinde M. S. 2009. Nutritional and *roti* quality of sorghum genotypes. *Indonesian Journal of Agriculture Science*, 10: 80-87.

Chavan, U. D., S.V. Nirmal, M.S. Shinde, G.H. Pawar, S.R. Gadakh and U.S. Dalvi 2017a. Nutritional quality of hybrid sorghum genotypes. *Int. J. Curr. Microbiol. App. Sci.,* 6(2): 586-592.

Chavan, U.D., Bhagwat, V.R., Ratnavati, C.V., Patil, J.V., Gawali, H.S and Shailaja, V. 2010. Jwariche Ruchakar Padartha. Sorghum Research Centre, Rajendranagar, Hyderabad (India) .pp. 26

Chavan, U.D., Chavan, J.K. and Kadam, S.S. 1988. Effect of fermentation on soluble proteins and *in-vitro* protein digestibility of sorghum, green gram and sorghum + green gram blends. *J. Food Sci.*, 53 : 1574-1575.

Glover, J., Walker, C., and Mattern, P. 1986. Functionality of sorghum flour components in a high ratio cake. *Journal of Food Science.* 51: 1280–1283, 1292.

Klopfenstein, C. F. and Hoseney, R. C. 1995. Nutritional properties of sorghum and millets. Dendy, D. A. V 125 St Paul, Minn.: American Association of Cereal Chemistry.

Michniewicz, J., Biliaderis, C. G. and Bushuk, W. 1991. Effect of added pentosans on some physical and technological characteristics of dough and gluten. *Cereal Chemistry* 68: 252–258.

Murty D. S. and Subramanian V. 1981. Sorghum Roti: I. Traditional Methods of Consumption and Standard Procedures for Evaluation. Proceedings of the *International Symposium on Sorghum Grain Quality*: 73-78.

Nandini C. D. and Salimath, P. V. 2001. Structural features of arabinoxylans from sorghum having good roti-making quality. *Food Chemistry.,* 74: 417 - 422.

Nirmal, S.V., Shinde, M. S., Awari, V. R., Patil, V. R., Gadakh, S. R., Dalvi, U. S. and Chavan, U. D. 2017. RSSV 313: A Sweet Sorghum Donor for High Biomass. *Int. J. Curr. Microbiol. App. Sci*., 6(3): 907-912.

Panse, V. G. and Sukhatme, P. V. 1967. Statistical Methods for Agricultural Workers 2nd Edn. I.C.A.R., New Delhi.

Rao Prasada, K. E. and Murty, D. S. 1981. Sorghum for Special Uses. *Proceedings of the International Symposium on Sorghum Grain Quality*: 129-134.

Shobha, V., Kasturiba, B., Naik, R. K. and Yenagi, N. 2008. Nutritive Value and Quality Characteristics of Sorghum Genotypes. *Karnataka Journal of Agriculture Science*., 20: 586-588

Subramanian, V. and Jambhunathan, R. 1982. Properties of sorghum grain and their relationship to rot quality. In: International Symposium on sorghum grain quality. ICRISAT, Patancheru, India. pp. 280-288.

Subramanian, V. and Jambunathan, R. 1981. Properties of Sorghum Grain and their Relationship to Roti Quality. *Proceedings of the International Symposium on Sorghum Grain Quality*: 286-288.

Vietor, R. J., Angelino, S. A. G. F. and Voragen, A. G. J. 1992. Structural features of arabinoxylans from barley and malt cell wall material. *Journal of Cereal Science*., 15: 213–222.

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