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VT Sarate
M.Sc. Student, Department of Biochemistry, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

US Dalvi
Associate Professor of Biochemistry, Sorghum Improvement Project, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

S Shiney
PhD. Student, Department of Biochemistry, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

AS Kamble
M.Sc. Student, Department of Biochemistry, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

PS Yevle
M.Sc. Student, Department of Biochemistry, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Y Gautam
PhD. Student, Department of Genetics and Plant breeding, Rajasthan Agriculture Research institute, durgapura Jaipur Rajasthan, India

SJ Deshmukh
M.Sc. Student, Department of Plant Pathology, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

HH Zode
M.Sc. Student, Department of Microbiology, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Corresponding Author:
VT Sarate
M.Sc. Student, Department of Biochemistry, Post Graduate Institute, Mahtma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India

Effect of roasting on biochemical attributes in hurda sorghum

VT Sarate, US Dalvi, S Shiney, AS Kamble, PS Yevle, Y Gautam, SJ Deshmukh and HH Zode

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Abstract
The study aims to provide insights in to optimizing the roasting process to enhance the nutritional benefits of sorghum hurda while maintaining its traditional sensory qualities. Three roasting methods were used, namely open fire roasting, pan roasting, and oven roasting for study the effect on nutritional parameters particularly moisture, protein, sugars and phenol content. Among the eight sorghum hurda genotypes studied, RSSGV-89, Phule Madhur and Phule Uttara were found superior in nutritional quality, showing higher levels of protein, and sugars across treatments. Pan and microwave roasting preserved nutrient content better than open fire roasting method.

Keywords: Sorghum, Hurda, Genotype, Roasting, Nutritional Parameters

Introduction
Sorghum (*Sorghum bicolor* L), a major cereal crop globally, is highly valued for its adaptability to various environmental conditions, especially in arid and semi-arid regions. Known for its drought resistance, sorghum plays a crucial role in food security, particularly in developing countries. It is an important food source for millions of people due to its ability to survive in harsh weather conditions. There is a considerable variation in sorghum for levels of proteins, lysine, lipids, carbohydrates, fiber, calcium, phosphorus, iron, thiamine and niacin (Shobha *et al*., 2008) [28]. Sorghum is rich in fiber and minerals, apart from having a sufficient quantity of carbohydrates (72%), proteins (11.6%) and fat (1.9%). Maharashtra is the largest producer (37.88%) of sorghum followed by Karnataka (20.68%). In Maharashtra, the major sorghum producing districts are Osmanabad, Nanded, Yavatmal, Buldhana, Parbhani, Kolhapur, Solapur, Amravati, Pune and Ahilyanagar (Gautam and Singh, 2018) [12].
Tender sorghum, known as "Hurda" in some regions, is a widely grown cereal crop, especially in dry areas where other crops may not grow well. In India, sorghum is harvested and consumed at the milky stage in parts of North Karnataka and South Maharashtra and is known by different regional names *viz*., seethani in Karnataka and hurda in Maharashtra. Particularly in the developed countries there is growing demand for gluten free foods and beverages from people with celiac disease and other intolerances to wheat that cannot eat products from wheat, barley or rye. Tender jowar which is highly seasonal and available only for a limited period (Meti *et al*., 2014) [17].
Roasting is a common method used to process tender hurda sorghum. Roasting is a heat treatment process that involves exposing food to dry heat, typically at high temperatures. However, roasting can also affect the nutritional value of the grain, it might change the amount of proteins, vitamins, or minerals available in sorghum, which can impact its health benefits. However, roasting can also induce physical and chemical changes in the food matrix, which can affect the nutritional quality (Gwekwe *et al.,* 2024) [13]. Roasting, including pan and dry heat methods, significantly alters the nutritional and antioxidant properties of cereal grains. Roasting improves the energy value by increasing carbohydrate and fat content, while reducing moisture and crude fiber. Although the process slightly decreases protein content due to Maillard reaction and amino acid degradation (Oboh *et al*., 2010) [19]. Roasting significantly improves the sensory attributes of grains, including colour, aroma, and taste. Maillard reactions during heat treatment contribute to the formation of melanoidins,

which impart a brown colour and roasted flavour (Lohinova and Petrusha, 2023) [16]. Open fire roasting, commonly used in rural processing of tender sorghum (hurda), imparts a unique smoky flavour but may cause uneven roasting (Bhosale *et al*., 2007) [6]. Open fire roasting is a traditional method in which the grains are directly exposed to flame or hot sand in shallow pans. It is widely used in preparing hurda in rural Maharashtra. According to Bhosale *et al.* (2007) [16], this method develops a unique flavour and crisp texture but leads to variable heating, which may result in partial nutrient loss. Pan roasting involves dry heating with continuous stirring, which enhances aroma and flavour (Singh *et al*., 2013) [29]. Pan roasting has been reported to improve antioxidant properties and enhance shelf life. (Wani and Kumar 2017) [36] while oven roasting provides even heating and better retention of nutrients (Deshmukh *et al*., 2015) [10].

The purpose of this study is to examine the effect of roasting on the nutritional quality of hurda, by understanding the impact of roasting; the study aims to provide insights in to optimizing the roasting process to enhance the nutritional benefits of hurda while maintaining its traditional sensory qualities. The findings will help in understanding how traditional food processing techniques like roasting can influence the nutritional profile of sorghum-based foods, contributing to the development of healthier and more nutritious products (Weerasooriya *et al*., 2018) [37].

Materials and Methods

Hurda grain sorghum genotypes included in the investigation are as below and were obtained from Sorghum Improvement Project, MPKV, Rahuri.

Table 1: List of hurda grain sorghum genotypes used for study

Sr. no.	Name of genotype	Sr. no.	Name of genotype
1	RSSGV 83	5	RSSGV 91
2	RSSGV 86	6	RSSGV 93
3	RSSGV 87	7	Phule Madhur
4	RSSGV 89	8	Phule Uttara

Experimental methods

For the control samples, 50 grams of Hurda from each genotype was threshed, separated, and cleaned properly. Organoleptic parameters such as colour, taste, and texture were recorded for each genotype. After that, nutritional parameters including moisture, reducing sugar, non-reducing sugar and total sugar content were estimated. Once the moisture analysis was completed, the remaining hurda was ground using a mixer grinder. The powdered sample was then used for estimation of ash, crude protein, and crude fibre content.

Roasting methods

In this study three roasting methods were used, namely open fire roasting, pan roasting, and oven roasting. In open fire roasting, fresh hurda cobs from each genotype were directly roasted on a traditional chulha without threshing. Each genotype was roasted for about 2 to 4 minutes, and immediately after roasting, the hot cobs were threshed, and the hurda was separated and cleaned. In pan roasting, raw hurda was first threshed, separated, and cleaned. Then, each genotype was roasted separately on a hot pan for about 1.15 to 2 minutes. In oven roasting, similarly cleaned and separated hurda was roasted in a hot air oven for about 3 minutes for each genotype.

Nutritional parameter analysis

Moisture ash and crude fiber content of tender hurda grain was determined by employing the standard method of analysis (AOAC, 1965). Crude protein content was estimated by multiplying per cent nitrogen by 6.25. Total nitrogen in flour was estimated by Micro-Kjeldahl method (AOAC, 2000). Reducing sugars were determined by Somogyi's modified method (1952). (Somogyi, 1952; Krishnaveni *et al*., 1984) [30, 15]. Total sugar percentage was calculated by the method suggested by Sadasivam and Manickam (1992) [24]. Statistical data analysis was carried out as per Factorial Randomized Block Design.

Results and Discussion

Moisture

Moisture content is a key quality indicator for hurda sorghum grains, directly influencing the nutritional as well as sensory evaluation like colour, texture, taste. In the present investigation, the moisture content across all genotypes and roasting methods ranged from 37.54% to 54.96% with an overall mean of 44.35%. Moisture content varied significantly among different roasting treatments and genotypes. The highest average moisture was recorded in T_0 (Fresh hurda- 53.64%) and the lowest in T_2 (Open fire - 39.03%). Among genotypes, RSSGV-83 showed the highest mean moisture (46.16%), while RSSGV-87 showed the lowest (42.90%). The maximum moisture (54.96%) was observed in RSSGV-83 under control, whereas the minimum (37.54%) was in Phule Madhur under T_2 (Open fire) (Table 2). The statistical analysis revealed significant differences among treatments and genotypes, while their interaction (G×T) was non-significant, indicating uniform effects of treatments across genotypes.

According to Shiney *et al*., 2024 [27] at the soft dough stage, the highest moisture content was found in genotype RSSGV-89 (56.79 %), while the lowest was seen in genotype RSSGV-84 (38.22 %). During the hard dough stage, genotype RSSGV-89 again showed the highest moisture content (34.89 %), and the lowest was recorded in genotype RSSGV-84 (21.89 %). In the mature stage, genotype RSSGV-89 had the highest moisture content (12.59 %), whereas the lowest was observed in genotype RSSGV-84 (7.26 %). Chavan *et al.* (2013) [7] reported the maximum moisture content of 57.55% in genotype RSSGV-46, followed by Phule Uttara with 56%, supporting the moisture trends observed in this study. Hurda roasting study with varieties like Sakkari Mukkari Jola and M35-1 showed that trench, oven (150 °C for 15-25 min), and microwave (2-3 min) methods influenced quality (Patil *et al*., 2010) [21]. Oven roasting was best at 20 min, while microwave for 2.5 min gave clean, soft grains with better threshability and shelf-life. The variety Sakkari Mukkari Jola showed higher moisture before roasting (58%) and also after roasting (ranging from 52.1% to 55.8%), compared to Raosaheb, which had a maximum moisture of 52.2% and a minimum range of 29.5% to 49.9%. Moisture retention was optimum in microwave-roasted hurda, making it commercially suitable (Patil *et al*., 2010) [21].

Table 2: Effect of roasting methods on moisture (%) of hurda sorghum genotypes.

Genotype / Treatment	RSSGV83	RSSGV86	RSSGV87	RSSGV89	RSSGV91	RSSGV93	P. Madhur	P.Uttara	Mean
T_0	54.96	54.88	52.03	53.22	54.05	53.48	52.84	53.68	53.64
T_1	44.13	43.15	40.95	42.58	41.36	43.52	43.92	42.46	42.76
T_2	40.35	41.22	38.50	39.68	37.84	38.61	37.54	38.47	39.03
T_3	45.21	44.35	40.12	41.33	40.38	42.54	41.38	40.58	41.99
Mean	46.16	45.90	42.90	44.20	43.41	44.54	43.92	43.80	44.35
	SE±(m)	CD@5%							
T	0.44	1.22							
G	0.62	1.73							
GXT	1.25	NS							

Where,
T_0= Fresh hurda ; T_1= Pan roasting ; T_2= Open fire; T_3= Microwave oven roasting

Ash

Ash content is an important nutritional attribute of hurda sorghum grains, contributing to the overall mineral composition and quality. In the present investigation, the ash content across all genotypes and treatments ranged from 1.48% to 2.64%, with an overall mean of 2.10%. Ash content varied significantly among different roasting treatments and genotypes. The average ash content was recorded highest in T_2 (Open fire - 2.31%) and the lowest in T_0 (Fresh hurda - 1.69%). Among genotypes, Phule Uttara showed the highest mean ash content (2.40%), while RSSGV-93 showed the lowest (1.87%). The maximum ash content (2.64%) was observed in Phule Uttara under T_2 (Open fire), whereas the minimum (1.48%) was in RSSGV-86 under T_0 (Fresh hurda) (Table 3).

The results obtained were in close conformity with the range of ash content 1.63 to 2.90 per cent reported by Pontieri *et al.* (2014) [23]. Similar results were obtained by Patekar *et al* (2017) [20] with ash content ranging from 1.21 to 1.45 per cent. Jimoh and Abdullahi (2017) [2] revealed similar results where ash content of sorghum grains ranged 1.12 to 1.68 per cent. Similar results were stated by Anerao *et al.* (2022) [3] where ash content in the white sorghum, yellow sorghum and red sorghum was recorded in the range of 1.39, 1.57 and 1.90 per cent respectively. The results obtained in the present investigation are in harmony with the earlier reports. Ash content of sorghum increased from 3.6% to 4.2% due to roasting, suggesting enhanced mineral availability post-processing (Gwekwe *et al.*, 2024) [13].

Table 3: Effect of roasting methods on ash (%) of hurda sorghum genotypes.

Genotype / Treatment	RSSGV83	RSSGV86	RSSGV87	RSSGV89	RSSGV91	RSSGV93	P. Madhur	P. Uttara	Mean
T_0	1.74	1.48	1.50	1.88	1.62	1.54	1.84	1.90	1.69
T_1	2.15	1.94	2.25	2.31	2.00	1.84	2.26	2.48	2.15
T_2	2.35	2.02	2.38	2.45	2.15	2.10	2.40	2.64	2.31
T_3	2.20	2.12	2.28	2.38	2.10	1.98	2.21	2.58	2.23
Mean	2.11	1.89	2.10	2.26	1.97	1.87	2.18	2.40	2.10
	SE±(m)	CD@5%							
T	0.03	0.08							
G	0.02	0.06							
GXT	0.06	NS							

Crude fiber

Crude fibre content is an important nutritional parameter in hurda sorghum grains, influencing the digestibility and textural characteristics of the product. In the present investigation, the crude fibre content across all genotypes and treatments ranged from 2.25% to 2.95%, with an overall mean of 2.60%. Crude fibre content varied significantly among different roasting treatments and genotypes. The highest average crude fibre was recorded in T_1 (Pan roasting - 2.76%) and the lowest in T_0 (Fresh hurda - 2.48%). Among genotypes, RSSGV-89 showed the highest mean crude fibre (2.75%), while RSSGV-83, RSSGV-86 and Phule Madhur showed the lowest (2.51%). The maximum crude fibre (2.95%) was observed in RSSGV-87 under T_3 (Microwave oven roasting), whereas the minimum (2.25%) was in RSSGV-83 under T_0 (Fresh hurda) (Table 4). The statistical analysis revealed significant differences among treatments and genotypes, while their interaction (G×T) was non-significant, indicating uniform effects of treatments across genotypes.

Similar results were obtained by Jimoh and Abdullahi *et al.* (2017) [2] in sorghum genotypes with crude fiber ranging from 1.65 to 7.94 per cent. The results were in agreement with those obtained by Vannali *et al.* (2008) while working on ten sorghum genotypes for the physiochemical analysis, obtained a high crude fiber content of 2.48 per cent in Giddamaladandi variety. Gajmal *et al.* (2021) [11] had reported the crude fiber in a range of 2.24 to 2.59 per cent. Similar results were stated by Anerao *et al.* (2022) [3] where fiber content in the white sorghum, yellow sorghum and red sorghum was recorded in the range of 2.80, 3.00 and 3.20 per cent respectively. Findings revealed that a slight change in fiber content was observed after roasting. Thermal processing might cause partial degradation of dietary fiber structures (Pillai *et al.*, 2021) [22].

Table 4: Effect of roasting methods on crude fiber (%) of hurda sorghum genotypes

Genotype / Treatment	RSSGV83	RSSGV86	RSSGV87	RSSGV89	RSSGV91	RSSGV93	P. Madhur	P. Uttara	Mean
T_0	2.25	2.30	2.35	2.60	2.55	2.60	2.65	2.50	2.48
T_1	2.75	2.65	2.85	2.95	2.90	2.85	2.55	2.60	2.76
T_2	2.55	2.70	2.50	2.70	2.25	2.65	2.25	2.65	2.53
T_3	2.50	2.40	2.95	2.75	2.70	2.65	2.60	2.60	2.64
Mean	2.51	2.51	2.66	2.75	2.60	2.69	2.51	2.59	2.60
	SE±(m)	CD@5%							
T	0.03	0.07							
G	0.04	0.10							
GXT	0.07	0.20							

Crude protein

Crude protein content is a key nutritional parameter in hurda sorghum grains, essential for evaluating the dietary value and functional quality of the product. In the present investigation, the crude protein content across all genotypes and treatments ranged from 8.10% to 10.84%, with an overall mean of 9.41%. Crude protein content varied significantly among different roasting treatments and genotypes. The highest average crude protein was recorded in T_0 (Fresh hurda) with 10.15% and the lowest in T_2 (Open fire) with 9.12%.Among genotypes, RSSGV-83 showed the highest mean crude protein9.89%, while RSSGV-89 showed the lowest 8.69%. The maximum crude protein 10.84% was observed in RSSGV-83 under T_0 (Fresh hurda), whereas the minimum 8.10% was in RSSGV-89 under T_1 (Pan roasting) (Table 5).

These results are in close conformity with the observation obtained by Abdelhalim *et al*. (2019) [1] in wild sorghum genotypes with the range of 10.30 to 14.60 per cent. Crude protein content ranging from 10.39 to 11.33 per cent was reported in the earlier studies by Sulaiman *et al*. (2020) [31]. As documented earlier by Tasie and Gebreyes (2020) crude protein ranged between 8.20 to 16.48 per cent. Similar results were obtained by Mohammed *et al.* (2019) [18] in red sorghum, white sorghum and yellow sorghum with crude protein content of 6.06, 4.82 and 4.27 per cent respectively. It concluded that hurda having better nutritive quality than matured sorghum grain (Shinde *et al*., 2016) [25]. Takruri *et al.* (1990) [32] proved that the protein quality of milky stage grain is better than the harvesting stage grain. The results obtained in the present investigation are agreement with the earlier reports.

Table 5: Effect of roasting methods on crude protein (%)of hurda sorghum genotypes.

Genotype / Treatment	RSSGV83	RSSGV86	RSSGV87	RSSGV89	RSSGV91	RSSGV93	P.Madhur	P. Uttara	Mean
T_0	10.84	10.28	10.65	9.20	9.55	9.65	10.25	10.75	10.15
T_1	9.80	8.95	9.35	8.10	9.18	9.10	9.45	9.84	9.22
T_2	9.28	9.20	9.60	8.56	8.95	8.78	9.15	9.42	9.12
T_3	9.64	9.46	9.24	8.90	8.56	9.05	9.08	9.18	9.14
Mean	9.89	9.47	9.71	8.69	9.06	9.15	9.48	9.80	9.41
	SE±(m)	CD@5%							
T	0.09	0.26							
G	0.13	0.36							
GXT	0.26	NS							

Reducing sugar

Reducing sugar content plays a significant role in determining the sweetness and overall palatability of hurda sorghum grains, making it a key factor in sensory evaluation. In the present investigation, the reducing sugar content across all genotypes and treatments ranged from 2.04% to 3.26%, with an overall mean of 2.58%. Reducing sugar content varied significantly among different roasting treatments and genotypes. The highest average reducing sugar was recorded in T_0 (Fresh hurda) with 2.88% and the lowest in T_3 (Microwave roasting) with 2.40%. Among genotypes, Phule Uttara showed the highest mean reducing sugar (3.03%), while RSSGV-93 showed the lowest (2.19%). The maximum reducing sugar (3.26%) was recorded in Phule Uttara under T_0 (Fresh hurda), whereas the minimum (2.04%) was in RSSGV-83 under T_3 (Microwave roasting). The statistical analysis revealed significant differences among treatments, genotypes, and their interaction (G×T), indicating differential responses of genotypes to various roasting treatments (Table 6).

Darekar *et al*. (2020) [8] reported reducing sugar percentage 1.03 to 1.12 per cent in parching sorghum genotypes. Anerao *et al*. (2022) have previously documented the results stating that reducing sugars percentage of Indian major millet (jowar) with the range of 0.21 to 0.26 per cent. The findings of the present study are in similar trend with the prior investigation. Microwave roasting significantly reduced the content of reducing sugars in groundnut kernels, likely due to caramelization and Maillard reactions occurring during high-temperature treatment (Verma *et al.*, 2022) [35].

Table 6: Effect of roasting methods on reducing sugar (%)of hurda sorghum genotypes.

Genotype / Treatment	RSSGV83	RSSGV86	RSSGV87	RSSGV89	RSSGV91	RSSGV93	P.Madhur	P. Uttara	Mean
T_0	3.02	2.56	2.96	3.10	2.65	2.38	3.12	3.26	2.88
T_1	2.57	2.41	2.22	3.01	2.37	2.18	3.00	3.05	2.60
T_2	2.28	2.08	2.31	2.84	2.24	2.07	2.84	2.97	2.45
T_3	2.04	2.20	2.18	3.03	2.31	2.12	2.45	2.84	2.40
Mean	2.48	2.31	2.42	3.00	2.39	2.19	2.85	3.03	2.58
	SE±(m)	CD@5%							
T	0.03	0.07							
G	0.04	0.10							
GXT	0.07	0.20							

Total sugar

Total sugar content is a crucial parameter influencing the sweetness and energy value of hurda sorghum grains, making it important for both nutritional and sensory quality. In the present investigation, the total sugar content across all genotypes and treatments ranged from 2.89% to 5.48%, with an overall mean of 4.30%. The highest average total sugar was recorded in T_0 (Fresh hurda) with 4.61% and the lowest in T_2 (Open fire) with 4.10%. Among genotypes, Phule Uttara showed the highest mean total sugar (5.12%), while RSSGV-93 showed the lowest (3.02%). The maximum total sugar (5.48%) was observed in Phule Uttara under T_0 (Fresh hurda), whereas the minimum (2.89%) was in RSSGV-93 under T_2 (Open fire) (Table 7).

These results are similar to the values reported by Shinde *et al.* (2016) [25] the result revealed that Phule Uttara showed maximum total sugar percentage of 5.36 per cent, superior over RSSGV-46 with 5.09 per cent. Chavan *et al.*, reported that the total sugar percentage varied from 1.13 to 2.27 per cent. The results obtained in the present investigation are agreed with the earlier reports. According to Oboh *et al.*, (2010) [19] roasting of maize significantly increased the carbohydrate content as observed in both yellow and white varieties. This rise in carbohydrate may be attributed to moisture reduction and concentration effect due to thermal treatment.

Table 7.Effect of roasting methods on total sugar (%)of hurda sorghum genotypes**.**

Genotype / Treatment	RSSGV83	RSSGV86	RSSGV87	RSSGV89	RSSGV91	RSSGV93	P.Madhur	P. Uttara	Mean
T_0	4.75	4.12	4.46	5.12	4.44	3.18	5.32	5.48	4.61
T_1	4.17	4.06	4.06	4.89	4.25	3.04	5.10	5.12	4.34
T_2	4.02	3.89	3.84	4.42	4.02	2.89	4.87	4.87	4.10
T_3	4.22	3.49	3.72	4.68	4.30	2.97	4.98	5.00	4.17
Mean	4.29	3.89	4.02	4.78	4.25	3.02	5.07	5.12	4.30
	SE±(m)	CD@5%							
T	0.04	0.12							
G	0.06	0.17							
GXT	0.12	NS							

Conclusıon

Among the eight sorghum hurda genotypes studied, RSSGV-89, Phule Madhur and Phule Uttara were found superior in nutritional quality, showing higher levels of protein, and sugars across treatments. Pan and microwave roasting preserved nutrient content better than open fire roasting method. Overall, genotype RSSGV-89 was found consistently superior across nutritional studies, followed closely by Phule Madhur, suggesting both genotypes hold strong potential for future hurda commercialization and research applications.

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