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Functional, Nutritional and Thermal properties of Extruded Browntop Millet Flours

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ABSTRACT: Millets would be widely used if processing were improved and if sufficient good quality flour were made available to meet the demand. Quality flour production suitable to various products could be possible when there is complete evaluation of millet flours using different processing techniques hence the present study focused on evaluating the impact of extrusion cooking on the functional, nutritional, thermal characteristics and shelf life of browntop millet flour. Whole and dehulled browntop millet grits were extruded at 140, 150°C respectively and made into flour for further analysis following standard procedures. The swelling power of analysed samples ranged from 203.0±0.6 to 621.3±0.9 with DBF (Dehulled Browntop millet Flour) being the least and DEBF the highest. Significant improvement upon extrusion was observed for WAC%, WHC%, OAC% and ORC%. Moisture content varied from 7.43±0.27 to 8.99±0.06. Significant reduction in the moisture content upon extrusion was noted but no great enhancement in the protein content. The ash content of the analysed flours ranged from 2.16±0.17% in EWBF to 5.43±0.27% in WBF. Decrease in the ash content was found in extruded samples. Fat content in the analysed samples was found to be in the range of 3.78±0.12% in EWBF to 6.27±0.15% in DBF, reduction in the fat content was observed due to extrusion. Carbohydrate content and calorific values were greater in the extruded browntop millet flour than native flours. Increase in the gelatinization temperatures (Onset *To* (°C), Peak *Tp* (°C), Conclusion *Tc* (°C)) and pasting temperature, pasting viscosity was observed in extruded browntop millet flours. The storage (G') and loss modulus (G") were reduced due to extrusion in whole and dehulled samples. Shelf life study indicated that moisture, water activity, TMC and TBC of the analysed samples were within the acceptable range. The results highlight the potential use of extrusion cooking to develop quality browntop millet flour with optimal nutritional composition, functional and thermal properties with good keeping quality.

Keywords: Browntop millet, extrusion, functional properties, nutritional properties, thermal properties.

INTRODUCTION

Extrusion cooking is used worldwide for the production of expanded snack foods, starch modified ready to eat cereals, baby foods, pasta and pet foods. This technology has many distinct advantages like versatility, low cost, better product quality and no process effluents (Abbott, 1987; Camire *et al*., 1990). It is one of the contemporary food processing technologies applied for preparation of variety of snacks, specialty and supplementary foods and offers advantages of preparation of ready-to-eat foods of desired shape, size, texture and sensory characteristics at very low processing cost (Guy, 2001). Extrusion processing technology was usually used in the food industry, especially grain processing, due to its advantages of high efficiency, low cost and convenience (Shivendra *et al*., 2010).

Browntop millet is one of the nutritious minor millets and called as called "Korale" in Kannada and

"Karlakki" in Mandya region and "Andukorralu" in Telangana and Andhra Pradesh, Karnataka. An understanding of suitable processing, salubrious alternatives, are key factors in determining the usage of Browntop millet for domestic consumption or product development with optimum nutrients.

In past few decades, the consumption of foods mainly based on refined flours has resulted in reduced intake of dietary fibre and other micronutrients as a result of urbanized lifestyles, changes in practices and level of physical activity. This may be associated with rising affluence induced by developmental transition contributed to increasing prevalence of overweight/obesity (Sindhi and Jain 2006). Of late, consumer inclination towards foods based on millet grains has brought the research on millet grains in forefront. However, millets are still considered as the food for poor and traditional consumers because of non-availability of ready-to-use or ready-to-eat convenience food products from the millet (FAO, 1995); (Varriano and Hoseney 1983) and also the limited efforts made to diversify its food uses by application of traditional and contemporary food-processing methods (Ali, 2003). With this backdrop present study was planned to evaluate effect of extrusion on functional, nutritional and thermal properties of browntop millet flour.

MATERIAL AND METHODS

Procurement of raw materials. Browntop millets were procured directly from the farmers and thoroughly cleaned to remove any foreign material, dust and light materials by using de-stoner. All the chemicals used for the investigation were of food grade and analytical reagent (AR) grade. Chemicals and glassware were obtained from the Post Graduate and Research Centre (PG & RC).

Extrusion. Both the whole and dehulled browntop millet grits were extruded in an extruder (BTPL Culcutta) with 3 mm die diameter at barrel temperatures 140 and 150°C respectively, with a feed moisture 20%**.** The setting of extrusion parameters refers to the study of Liu *et al*. (2020) with slight modification. The extrudates were ground and stored for further analysis.

Functional properties. The Swelling power was determined according to the procedure of Schoch (1942). Water absorption capacity (Awoyale *et al*., 2020). The oil retention capacity was determined as described by (Sosulski *et al*., 1976). Water Holding Capacity by Mesías and Morales (2017).

Nutrient analysis. Proximate composition of raw and processed millet flours was done using standard AOAC methods such as moisture-oven drying method (AOAC, 2005), ash-charring method (AOAC, 2005), protein-kjeldhal method (AOAC 992.23 - 2005), crude fiber-acid-base extraction method (AOAC 962.09 - 2016) and fat-soxhlet extraction method (AOAC 922.06 - 2016). Carbohydrate content was calculated by subtracting the total of moisture, fat, protein, and ash from 100. Energy values were obtained by the formula:

Energy value = Protein × 4 + Carbohydrate × 4+ Fat × 9

Pasting properties: Pasting properties were determined by using starch cell (Physica Smart, Starch analyzer-Anton Paar) attached to rheometer (MCR 52, Anton Paar, GmbH, Germany). Rheometer was operated by using Rheoplus software. Study was adopted according to the procedure (Jayakody *et al*., 2007).

Rheological properties: The rheological behavior of the doughs was studied by dynamic oscillatory measurements on Physica MCR 52 Rheometer (Anton Paar GmbH, Germany) equipped with parallel plate geometry (50 mm diameter) and a PP50 probe. Study was done according the procedure (Khatkar, 1995).

Shelf life study. Shelf life of the samples in the present study was studied by TMC, TBC, moisture content and water activity for 60 days of storage period. The population of bacteria and mould in flours was determined by using the method given by Thambekar *et al.* (2009). Water activity of the millet flours during the storage period was assessed in water activity meter by maintaining the constant temperature of 24 to 26°C.

Statistical analysis. All data were presented as means+ the standard deviation of the mean. As for multiple group comparison, the significance of the differences among the treatment groups and their respective control groups were analysed using Window stat 9.1 software. Statistical significance was assessed by one-way analysis of variance (ANOVA). Differences between means were considered statistically significant at 5% level.

RESULTS AND DISCUSSION

Functional properties of extruded BM flours. The functional properties of extruded browntop millet flours were given in the Table 1. The swelling power of analysed samples ranged from 203.0±0.6% to 621.3±0.9 with DBF (Dehulled Browntop millet Flour) being the least and DEBF the highest. Significant improvement in the SP was recorded for extruded samples. The water absorption capacity in the samples increased significantly upon extrusion as compared to their corresponding raw (unextruded) samples. During extrusion cooking denaturation of proteins occur especially albumins there by increasing the affinity for water absorption (Alonso *et al*., 2000). Water holding capacity varied from 98.9±0.5% (DBF) to 400.0±0.6% (DEBF), an increase was noted in WHC due to extrusion. An increase in the porosity of the extrudates with an increase in extrusion temperature and formation of smaller molecules due to starch dextrinisation during extrusion (Singh *et al.*, 2016) were the possible reasons for noticed improvements in the oil absorption and retention capacities in WEBF and DEBF respectively.

Table 1: Functional properties of extruded browntop millet flours.

Sample	SP	WAC %	WHC%	ORC%	OAC%
WBF	210.3±0.3 [c]	3.12±0.06[c]	109.2±0.6 [c]	2.03±0.03 [b]	2.10±0.05 [c]
DBF	203.0±0.6 [d]	2.09±0.04[d]	98.9±0.5 [d]	1.51±0.00 [c]	1.51±0.00 [d]
WEBF	501.7±0.9 [b]	20.5±0.26[a]	383.7±0.3 [b]	3.14±0.03 [a]	3.10±0.05 [b]
DEBF	621.3±0.9 [a]	16.23±0.4 [b]	400.0±0.6 [a]	3.57±0.03 [a]	3.70±0.05 [a]
CD	2.80	0.58	1.96	0.12	0.15

Values are expressed as ± standard deviation of three replications

WBF-Whole Browntop millet Flour; DBF- Dehulled Browntop millet Flour; WEBF-Whole Extruded Browntop millet Flour; DEBF-Dehulled Extruded Browntop millet Flour; SP-Swelling Power; WAC-Water Absorption Capacity; WHC-Water Holding Capacity; ORC-Oil Retention Capacity; OAC-Oil Absorption Capacity

Nutritional properties of extruded BM flours. Nutritional composition of analysed samples was given in the Table 2. Moisture content varied from 7.43±0.27% to 8.99±0.06%. Significant reduction in the moisture content upon extrusion was noted. Significant difference between WBF, DBF and WBF, DBF was observed at ($p<0.05$%). This profound reduction could prevent microbial activity and ensure shelf stability of the extrudates. Extrudates prepared from sorghum has moisture content of 1.2% (Devi *et al*., 2014) and 9.1% (Akande, 2013), however it depends on blend composition, feed moisture, barrel temperature and speed. During extrusion process, the feed moisture content gives driving force for the expansion and contributes to the gelatinization and rheological properties (Lazou and Krokida 2010). Present results pertaining to protein were in accordance with the findings of Singh *et al*. (2007) who observed no great enhancement in the protein content of extruded blends. Compared with the corresponding non-extruded blends (control), the extrusion treatment did not change the total protein content, however, it reduced the soluble protein (61-86%), the fat (69-92%) and the resistant starch contents (100%). The total starch content of all studied blends increased (2-19%) after extrusion.

Ash gives an exhibition of inorganic elements present in samples as minerals. The ash content of the analysed flours ranged from 2.16±0.17% in EWBF to 5.43±0.27% in WBF. Decrease in the ash content was found in extruded samples however it was not significant in case of EDBF. Control (unextruded whole and dehulled) samples had greater ash content than respective extruded counterparts. Crude fibre content in the analyzed samples was found to in the range of 5.53±0.52% (EDBF) to 16.33±0.23 % (WBF). Crude fiber content of whole extruded millet flours was higher than dehulled extruded millet flours and raw flours. Extrusion has shown a significant effect on crude fiber content. Similar observations were recorded by Yusuf *et al*. (2017) in sorghum extrudates.

Fat content in the analysed samples was found to be in the range of 3.78±0.12% in EWBF to 6.27±0.15% in DBF. Fat content was reduced in extruded whole and dehulled millet flours except in DEBF with no significance. Present findings are in line with findings of Arribas *et al*. (2017); Marzo *et al*. (2002); Arribas *et al*. (2019) in extruded chickpea, pea and rice flours respectively. The decline in fat content was related to the disappearance of lipids during the extrusion process, as lipids form complexes with starch and proteins resistant to the lipid extraction procedures (Singh *et al*., 2007; Alam *et al*., 2016).

Carbohydrate content of analysed samples was observed to range from 58.00 ±1.06% (WBF) to 77.70± 0.32% (EDBF). Significant difference was noted for all the samples. An enhancement of CHO in the extruded samples than unextruded counterparts was observed. This was in agreement with findings of Morales *et al*., 2015; Cardoso-Santiago and Areas, 2001; Arribas *et al*., 2019; Yusuf *et al*., 2017 in extruded lentil, chickpea, rice and sorghum. This increase of carbohydrates has been related to a mechanical-structure modification propagated by cell rupture during extrusion process (Arribas *et al*., 2019). Calorific values of analysed browntop millet flours ranged from 306.8 ±4.6 K. Cal in WBF to 384.3±1.7K.Cal in EDBF. Significant difference was noted for all the samples. Calorific values of analysed samples in the descending order was 384.3±1.7 K.Cal/100 g (EDBF), 375.8± 0.6 K.Cal/100 g (EWBF), 371.9 ±1.1 K.Cal/100 g (DBF), 306.8 ±4.6 K.Cal/100 g (WBF).

Table 2: Nutritional properties of extruded browntop millet flours.

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fibre (%)	CHO (%)	Energy K.Cal/100 g
WBF	8.99±0.06[a]	8.8±0.23[c]	4.6±0.27[b]	5.43±0.27[a]	16.33±0.23[a]	58.00 ±1.06[d]	306.8 ±4.6[d]
DBF	8.84±0.04[a]	17.31±0.25[a]	6.27±0.15[a]	2.36±0.09[c]	3.53±0.29[d]	61.54 ±0.20[c]	371.9 ±1.1[c]
EWBF	7.43±0.27[b]	7.74±0.20[c]	3.78±0.12[c]	3.54±0.22[b]	12.50± 0.32[b]	77.70± 0.32[a]	375.8± 0.6[b]
EDBF	7.82±0.08[b]	10.77±0.11[b]	4.86±0.18[b]	2.16±0.17[c]	5.53±0.52[b]	74.37±0.20[b]	384.3±1.7[a]
CD	0.49	1.56	1.58	0.38	0.54	1.57	6.16

Values are expressed as ± standard deviation of three replications

WBF-Whole Browntop millet Flour; DBF- Dehulled Browntop millet Flour; WEBF-Whole Extruded Browntop millet Flour; DEBF-Dehulled Extruded Browntop millet Flour

Thermal and pasting properties of extruded BM flours. Table 3 summarizes the impact of extrusion cooking on thermal properties of browntop millet flours. All the analysed samples exerted a significant differences (p<0.05) in the gelatinization temperatures (On set, Peak and Conclusion temperatures). An increase in the temperatures due to extrusion in both whole and dehulled browntop millet flours was observed. Among all the samples, EWBF (Extruded whole browntop millet flour) was recorded with higher gelatinization temperatures while DBF (Dehulled browntop millet flour) showed least values demonstrating the effect of extrusion. Possible reason could be breakdown of the cell walls, resulting in more starch release and higher crystallite structure proportions (Siwatch *et al.*, 2017). However Hoover and Manuel (1996), reported that gelatinization temperatures were higher for un-extruded black gram flour as compared to extruded black gram flour in contrary to the present findings.

There was no significant difference between PT (Pasting Temperature) of WBF and DBF whereas WEBF and EDBF exerted significant difference (p<0.05). Lower PT was noted for extruded BM flours compared to native flours. Pasting Viscosity (PV) reflect the variations in flour viscosity that occur when it is heated in excess water while being constantly stirred. Greater values of PV were observed for WBF and DBF whereas significant reduction in PV was observed due to extrusion in both whole and dehulled BM flours. This might be due to the fact that a higher degree of starch gelatinization and degradation during extrusion cooking. Peak viscosity (PKV) and Final Viscosity FV were reduced due to extrusion in whole and dehulled BM flours. Similar results were reported by Chonthira *et al*. (2014).

The storage (G') and loss modulus (G") of the untreated and extruded millet flours were shown in Fig. 1. Storage and loss modulus were reduced due to extrusion in dehulled samples even lower than loss modulus of WBF, DBF and WEBF. Storage modulus values were higher than those of loss modulus for EWBF and EDBF. Compared to whole, dehulled reference samples very low values were recorded for extruded samples. No interception was observed at any given point of strain range. As indicated in the Fig. 1, (G′) values of WBF were higher than WFBF however similar values were noted up to 10% of strain. "G" was found to be lower for WFBF than WBF suggesting solid elastic like behavior, and the result was in coherence with Yadav *et al*. (2012a); Ananthanarayan *et al*. (2018).

Table 3: Pasting properties of extruded browntop millet flours.

Sample	Onset, *To* (ºC)	Peak, *Tp*(ºC)	Conclusion, *Tc* (ºC)	PT [°C]	PV [cP]	PKV [cP]	FV [cP]
WBF	80.12±0.58[b]	82.80±0.25[b]	86.26±0.08[b]	75.28±0.39[a]	127.00±0.6[c]	6185.00±1.00[b]	6628.00±2.00[b]
DBF	71.69±0.38[d]	71.69±0.21[d]	75.21±0.07[d]	74.73±0.32[a]	128.00±0.6[c]	16150.00±0.00[a]	13390.00±2.00[a]
EWBF	91.21±0.32[a]	91.21±0.06[a]	93.14±0.36[a]	65.00±0.58[b]	490.85±3.4[a]	1008.00±1.00[c]	2147.00±1.00[c]
EDBF	75.04±0.02[c]	75.04±0.01[c]	79.36±0.11[c]	50.00±0.58[c]	203.32±0.4[b]	1369.00±1.00[b]	1617.00±1.00[d]
CD	1.27	0.57	0.59	1.78	6.38	4.22	7.07

Values are expressed as ± standard deviation of three replications

WBF-Whole Browntop millet Flour; DBF- Dehulled Browntop millet Flour; WEBF-Whole Extruded Browntop millet Flour; DEBF-Dehulled Extruded Browntop millet Flour

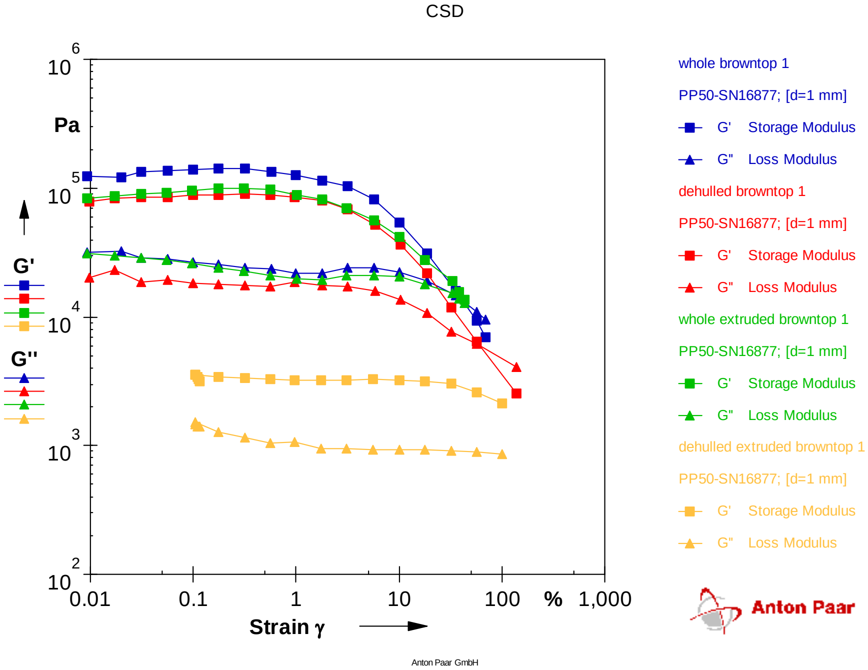

Fig. 1. Rheogram of extruded whole vs dehulled browntop millet flour doughs.

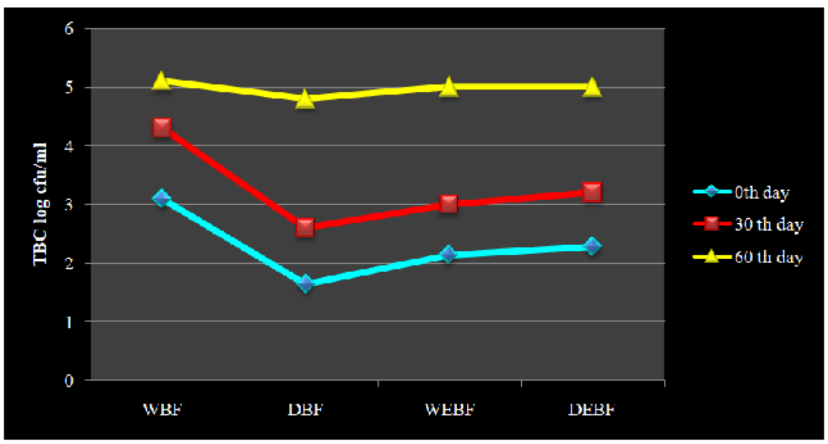

Fig. 2. TBC of extruded browntop millet flours during storage period.

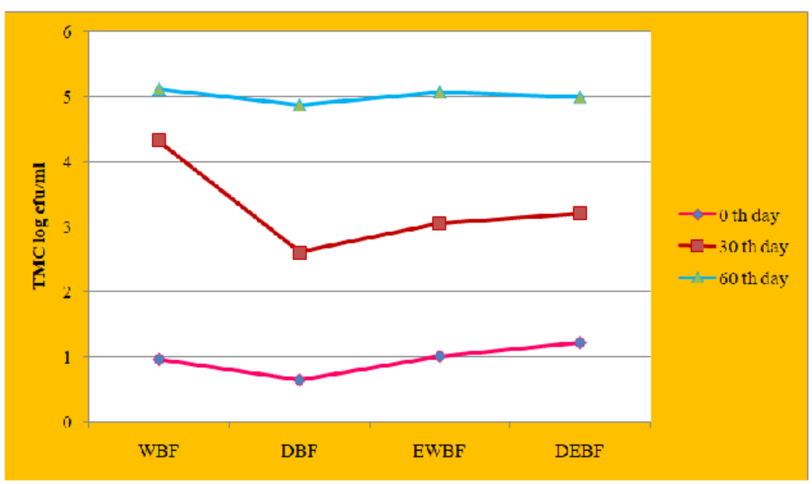

Fig. 3. TMC of extruded browntop millet flours during storage period.

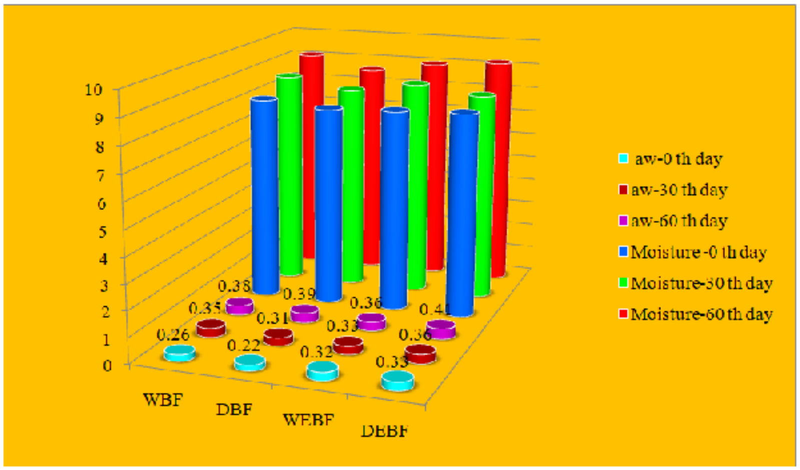

Fig. 4. Water activity and Moisture content of extruded browntop millet flours during storage.

Fig. 3 and 4 depicts the changes that occurred in bacterial and mold counts during the storage period, Bacterial count has varied from 1.65-3.1log cfu/ml while at the end of the storage period it was observed to be 4.8-5.1 log cfu/ml. TMC of analysed samples varied from 0.64-1.22 logcfu/ml on 0^{th} day while the range was 4.88-5.12 log cfu/ml on 60^{th} day. Moisture content was gradually increased from 0^{th} day to 60^{th} day of storage period in all the samples. Similar results were reported by Varsha and Aruna (2017), in biofortified pearl millet. Water activity (a_w) is an important means of predicting and controlling the shelf life of food products. It was increased consistently over the storage period (0^{th} –60^{th} day) for all the samples. Kriti *et al*. (2017) reported a 30% increase in the water activity during a storage period of 60 days in pearl millet pasta. This increase in the a_w might be due to hygroscopic nature of the flours, changes in the temperature and humidity. However, during the study period, moisture, water activity were under desirable levels. Thus, the shelf-life studies demonstrated that all the flours have better shelf life.

CONCLUSION

From the current study it can be concluded that utilization of either extruded whole or dehulled browntop flours are beneficial, however, a relative benefit is observed in extruded flours in terms of higher nutrients, better functional and thermal properties with good keeping quality.

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Conflict of Interest. None.

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