IMPACT OF MALTING ON NUTRITIONAL COMPOSITION AND ANTIOXIDANT ACTIVITY OF FINGER MILLET

Tahsin Kazi[1], Shankar **Laware**[2,] Sanjay **Auti**[3]*
1. Research Scholar, Department of Botany, H.P.T. Arts and R.Y.K. Science College, Nashik-422005. (M.S.), India
2. Principal, Arts, Commerce and Science College, Sonai, Tal-Newasa, Dist.Ahmednagar-414105. (M.S), India
3. Professor, Department of Botany, H.P.T. Arts and R.Y.K. Science College, Nashik-422005. (M.S.), India
*Email: autisanjay66@gmail.com /Mobile No: +91 9423080468

Abstract
Different bio-processing techniques are used for value additions and to enhance bioavailability and reduction of anti-nutritional factors. The present work aims to standardize the process of malting and to study its effect on nutritional and anti-nutritional components in accessions of finger millet. Grains of the 10 selected accessions were used to obtain malt of 24 and 36 hours. Twenty four hours malt proved to be best as it shows a significant reduction in tannin (50–80%) and phenol (35-50%). A decrease in protein (20-50%), carbohydrates contents (20-50%) and an increase in reducing sugar was noted (10-15%).
The decrease in carbohydrates content deals with the utilization of a major portion of soluble sugar during early germination for respiratory activity and less synthesis of α-amylase. Reduction in protein attributed to the activation of proteases and improves its bio-availability. Vitamin C does not show any significant changes. Malting causes a significant decrease in the amount of phenol, overall decrease was more than 50%. A significant reduction was noted in the case of T3, T8, T10, T14, and T15 in 24 hours. Significant antioxidant activity was noted, in the case of T2, T3, and T8 accessions. Studies revealed that prolonged malting process for the enhancement of nutritional components is not necessary. Longer the malting period, higher the losses in dry matter through respiration.

Key Words: Antioxidant activity, anti-nutritional compounds, finger millet, malting, nutritional compounds.

Received: 06.12.2021 Reviewed: 24.02.2022 Accepted: 25.02.2022

1. INTRODUCTION

Finger millet is nutritious millet with a fair amount of nutritious compounds, minerals, vitamins, dietary fibers, and phenolic compounds. Despite its nutritional values, the crop is highly neglected might be due to the presence of anti-nutritional factors like phytic acid, tannins, and trypsin inhibitors (Gunashree *et al.*, 2014). The presence of anti-nutritional factors limits the digestibility of proteins and carbohydrates by inhibiting their respective proteolytic and amylolytic enzymes (Mohammed *et al.*, 2011). Several techniques like, genetic modification, amino-acid fortification, supplementation with protein-rich sources, malting and fermentation (Mohammed *et al.*, 2011) have been used to enhance the nutritional and organoleptic qualities of cereal-based foods. Among these, malting is the most inexpensive traditional process; however, the standardization of process and effective bioprocessing is needed for a substantial increment in the nutritional qualities. Malting of finger millet improves its digestibility, sensory and nutritional quality. It has a pronounced effect on the lowering of the anti-nutrients (Pawar and Dhanvijay, 2007).
In the present work, efforts were made to standardize the malting process to enhance nutritional qualities and to minimize anti-nutritional compounds like tannin and phenolic compounds.

2. MATERIALS AND METHODS

2.1 Germplasm collection

Accessions of Finger millet (*Eleusine coracana*) were collected from Nashik and Kolhapur districts of Maharashtra, India. A total of 64 accessions were collected and the accession numbers were given to the collected accessions from T1 to T64. Collected accessions were screened for their

morphological and biochemical compounds to identify the potential accessions (Auti *et al.*, 2017, Kazi and Auti, 2017). Based on screening, the 10 potential accessions (T1, T2, T3, T5, T8, T10, T14, T15, T19, and T29) out of 64 accessions of finger millet have been selected. The Dapoli-1 variety developed by *Kokan Krishi Vidyapeeth*, Dapoli, Maharastra (India) was considered as control.

2.2 Malting of Finger millet

Finger millet grains were cleaned and washed thoroughly with water and 100 grams seeds were steeped in 200 ml of distilled water (w/v=1:2) for 12 and 16 hours at ambient temperature (30°C). After draining the water, germination was continued for 24 and 36 hours by keeping these seeds under wet muslin cloth with regular mixing in a dark room. Germinated seeds were kept for shade drying (30–35°C) for 2 days. Two different samples were procured of varying germination and soaking time (Table 1).

Table1. Different malting conditions.

	Steeping	Germination	Drying
Malt A	12 hours	24 hours	35^0C for 48 hours
Malt B	16 hours	36 hours	35^0C for 48 hours

The malted dried seeds were milled and passed through 100 square cm sieve to obtain fine flour and stored in airtight labeled plastic containers for further analysis.

2.3 Biochemical Analysis

Control and obtained malt samples of 10 accessions were analyzed for biochemical and antioxidant activity, using recommended standard procedures.

Nitrogen in the samples was estimated by the standard micro-Kjeldahl procedure and multiplied by the factor 6.25 to obtain crude protein. The total carbohydrates were estimated by Anthron reagent and reducing sugars by the dinitrosalicylic acid (DNSA) method (Nelson, 1944). Vitamin C was estimated by Ghosh *et al.*, (1966) method. The total phenols were analyzed by the Folin-Phenol reagent method as used by Farkas and Kiraly (1962) and Flavonoids by Aluminium chloride reagent according to the method of Chang *et al.*, (2002). Tannin was estimated by Folin–Denis method (Pearson 1976). The radical scavenging activity was determined by the DPPH assay method (Blois 1958).

2.4 Statistical Analysis

The triplicate data of nutritional contents were statistically analyzed by IBM-SPSS 9 (Software version- v20). Data, expressed as Mean ±SD was statistically analyzed using one-way ANOVA was used to compare means and significance was accepted at $p>0.01$.

3. RESULTS AND DISCUSSION

Obtained results show variation in the amount of nutritional, anti-nutritional components and antioxidant activity due to variation in the grains of selected accessions and germination time. Obtained results are shown in Figures 2 (a, b), 3(a, b), 4 (a, b), and 5 (a, b). In the present studies, malt obtained by twenty-four (24) hours duration proved to be significant as it causes a significant reduction in tannin (50-80%) and phenolic compounds (35-50%) and causes negligible dry matter loss and significant increase of nutritional components. Mbithi *et al.*, (2000) concluded that longer sprouting time results in a loss in dry matter through respiration without corresponding significant overall nutritional benefits. Malting involves the controlled germination of seed grain which activates or develops diastatic enzymes, catalyzes the hydrolysis of polymerized reserved food materials, notably proteins, starches and cell-wall content (Ogbonna 2011).

The standardized process of malting is depicted in Fig.1. Malting of selected accessions of finger millet has brought following changes in the nutritional, anti-nutritional and antioxidant activity.

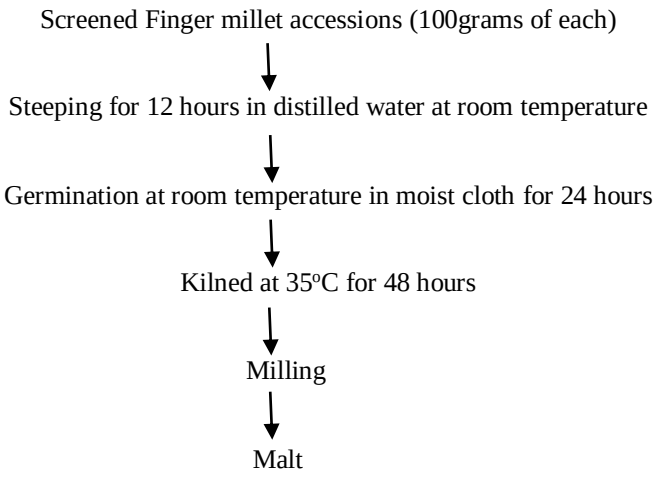

Figure 1. Process of Standardization of Malt (24 hours)

3.1. Proteins

The amount of protein in control showed a significant difference with un-malted and malted flour. All the selected accessions (T1 to T29) exhibit a decreasing trend except T10. In the case of T2, the amount of protein shows a 27% decrease after 24 (Malt-A) and 36 hours (Malt-B) of germination. A similar trend followed by the rest of selected accessions. More than 50% decrease in protein content was reported in a few accessions like T1 and T14 (Figure 2 a). The effect of germination and malting on protein seems to be conflicting. Our results are corroborated with Bhathal and Kaur (2015), Chavan and Kadam (1989). While Malleshi and Desikachar (1986) Saleh *et al.* (2013), Swami *et al.* (2013) and Laxmi *et al.* (2015) have reported an increase in the amount of protein after germination and sprouting.

Bhathal and Kaur (2015) have reported a reduction in total proteins and an increase in specific amino acids such as lysine, tryptophan, and methionine. The decrease may be associated with the activation of proteases during germination. Vidyavati *et al.* (2004) showed that the protease activity in finger millet increased with germination time, maximized on the third day, and decreased afterward. Malting activates proteases that degrade protein and improves its bioavailability (Mbithi *et al.*, 2000). Protein digestibility increased by 64% after germination of finger millet due to proteolysis and partial solubilization that comes with sprouting the seeds, as evidenced by -increased water-soluble proteins and frees amino acids in the sprouted seeds (Mbithi *et al.*, 2000).

3.2. Carbohydrates

A significant decrease in carbohydrates content was noted in two different malting conditions (24 and 36 hours). The overall decrease was found to be in the range of 20–50% in the first 24 hours and when germination was extended to 36 hours, marked reduction in the carbohydrate content was noted. In case of T1, T8 and T19 accessions, marginal decrease in carbohydrates content was observed in 24 hours malt but finally amount markedly decreased in 36 hours malt (Fig.2 b).

The decrease in carbohydrates deals with the utilization of a major portion of soluble sugar during early germination for respiratory activity (Nomura *et al.*,1969) and less synthesis of α-amylase. Mulimani and Supriya. (1993) has reported a decrease in amylase inhibitory activity with an increase in time during germination. Sharp changes in the amylase activity of 24–36 hours might be due to loss of dormancy, during which amylolytic enzymes which are synthesized in aleurone layer migrate to endosperm where the hydrolysis of starch starts (Glannie *et al.*, 1983).

The duration of the process is a significant factor in malting. At extended malting or germination, the enzymatic activity gets slow down.

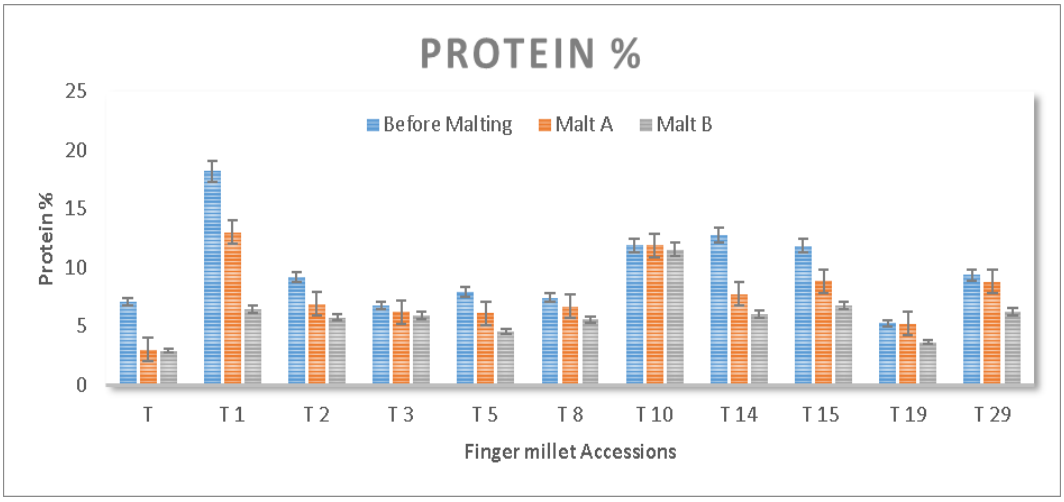

Figure 2(a): Amount of Protein before and after Malting.

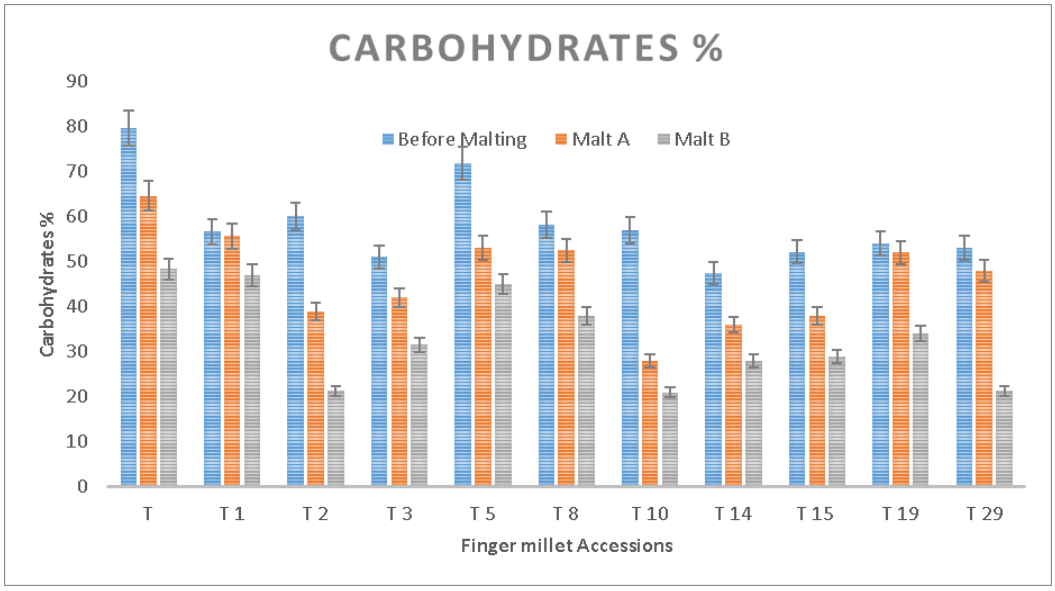

Figure 2(b): Amount of Carbohydrates before and after Malting.

3.3 Reducing Sugar

Reducing sugar content increases with an increase in germination time (24 and 36 hours). The maximum amount was noted in T1, T3, T5, T10, T14 and T19 accessions (10-15%). In the case of control, no significant increase was noted. The rest of the accessions showed a marginal increase in reducing sugar (3-5%) (Fig.3a). The results are in agreement with Mibithi *et al.*, (2000) and Banusha *et al.*, (2013). It is due to the hydrolysis of starch into reducing sugar by the activity of amylase during malting. The content of the reducing sugars in cereals was not significantly affected during the first 12 hours of germination, however, after 12 hours the content of reducing sugars increased by 20 folds which indicates increased enzymatic hydrolysis of starch (Zhang *et al.*, 2015). Mbithi *et al.* (2000) noted a similar trend in germinated seeds. Similar results were reported in rice by Vellupilai *et al.*, (2009).

3.4. Vitamin C

In our studies malting of finger millet grains does not bring any change in the content of Vitamin C during both the malting conditions. The amount of vitamin C in finger millet grains was found to be in range of 0.06–0.22 mg/100gm.Accessions T1, T3, T5, T14, and T15 show decreasing trend while in case T8, T10, T19 and T29 increase in the amount of Vitamin C was noted in 24 hours malt and sharp decrease was observed in 36 hours malt (Fig.3 b). This might be because of germination which occurs during malting. It utilizes nutrients for growth and development of the seedlings while contributing very little in terms of synthesis of compounds (Ochanda *et al.*, 2010). In contrast, Laxmi *et al.* (2015) noted an increase in Vitamin C content after malting. According to Verma & Patel (2013), some of the vitamins were synthesized and the bioavailability of minerals increases after malting.

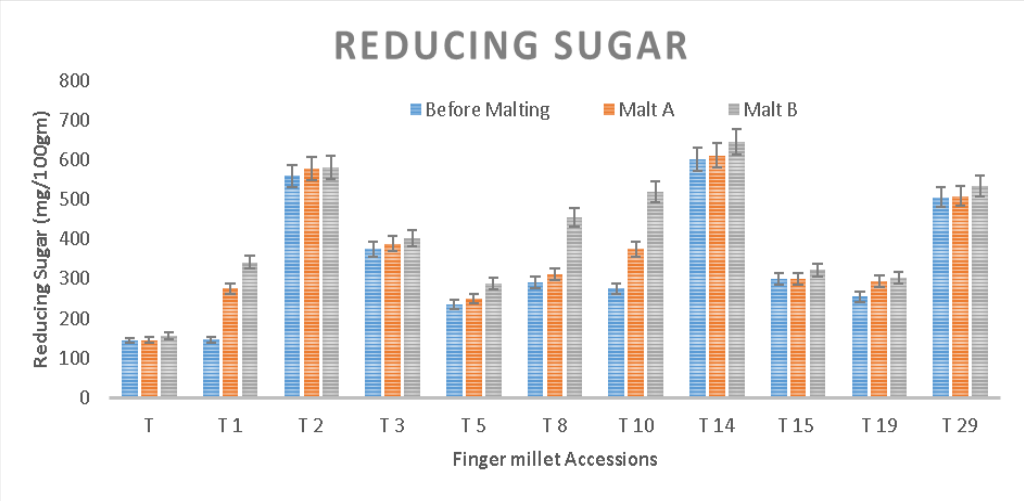

Figure 3 (a): Amount of Reducing sugar before and after Malting.

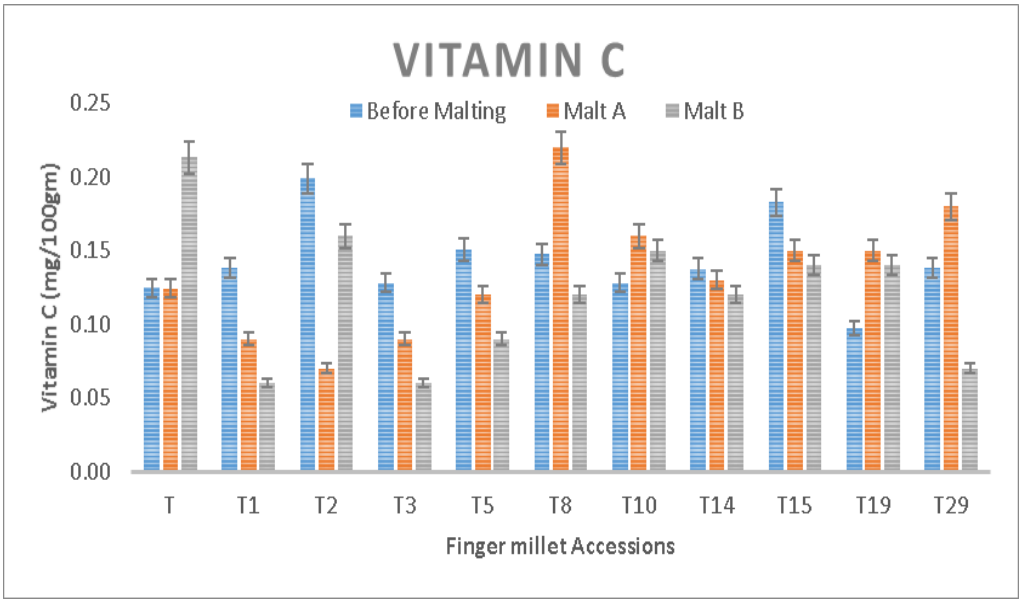

Figure 3(b): Amount of Vitamin C before and after Malting.

Vitamin C (ascorbic acid) content significantly increased in malted *Ragi* and wheat (Laxmi *et al.*, 2015). Vitamin C can be synthesized by plants and animals from glucose, mannose, and galactose (Banhegyi and Mandl 2001). Therefore, the increase in Vitamin C during malting- is driven by enzymatic hydrolysis of starch by amylases and diastases. This increases the availability of glucose for the biosynthesis of vitamin C. This enhanced content of glucose acts as a precursor to the formation of vitamin C (Desai *et al.*, 2010). In our finding it depicts that accessions that show an increased amount of Vitamin C in 24 hours malt can be co-related with the reduction in carbohydrate content in these accessions. Enhanced values of reducing sugar can also be co-related with the vitamin C content.

3.5 Phenol and Flavonoids

Malting shows a significant decrease in the amount of phenol over control. The overall decrease was more than 50%, while in the case of control Dapoli-1 marginal decrease was noted. A significant reduction was noted in the case of T3, T8, T10, T14, and T15 in 24 hours malt while the rest of the accessions show a marginal decrease in the phenol content (Fig.4 a). Accessions show a negative correlation between duration of germination and the amount of phenol. It was noted that in accession T5, phenol content increases in the first few hours but later on it shows a decreasing trend for 24 and 36 hours malt. The reason behind this increase could be the liberation of bound polyphenol and flavonoid contents by the structural break down of cell wall fibrils such as cellulose and hemicelluloses during the process of germination. Moreover, Glannie *et al.* (1983), reported variation in phenolic acid in sorghum varieties due to *de-novo* synthesis, followed by their storage in seeds instead of their migrating to shoots during malting.

The amount of flavonoids follows the significant decrease during malting except accession T19 and T29. Overall reduction was in the range of 41-84%. Accessions T1 and T8 show the maximum reduction of 84% and 78% respectively (Fig.4 b). Obtained results are in agreement with Abdelrahaman *et al.* (2007), Sripriya *et al.* (1996) and Maillard & Berset (1995).

According to Maillard & Berset (1995), variation in phenol content is due to genotypic specificity and specific profile. The present studies show that white finger millet grains have lower phenol contents (T2, 355mg/100gm) and brown finger millet (204 mg/100gm to 1371mg/100gm) are considerably rich due to higher content in the seed coat. The changes in the phenol content during malting can be attributed to the increased activity of induced endogenous enzymes and bioconversion of the phenolic compound as well as the loss of hydrolyzed phenolic compounds through leaching during steeping and germination (Hithamani & Srinivasan, 2017, Udeh *et al.*, 2018).

3.6 Tannin

Tannin content shows a decreasing trend during different durations of malt. In present studies in un-germinated seeds, tannin ranges from1350–1700 mg/100gm, after 24 hours 50% and after 36 hours 80% decrease was noted (Fig.5 a). Many researchers have reported the enhancement of nutritional compositions of millet by reducing the content of tannin (Gunashree *et al.*, 2014, Onyango *et al.*, 2013).

According to Butler *et al.* (1984), the reduction in tannin in germinated seed has been attributed to the formation of hydrophobic association with seed protein and enzyme and not due to degradation of tannin.

3.7 Antioxidant Activity during Malting

Antioxidant activity does not show any specific trend for selected accessions (Fig.5 b) in terms of percentage inhibition of free radicals by the DPPH method. In the case of T2, T3 and T8 accessions percentage inhibition activity increases rapidly from 73 – 94%, 69 – 94% and 63 – 89% respectively, in 24 hours malt.

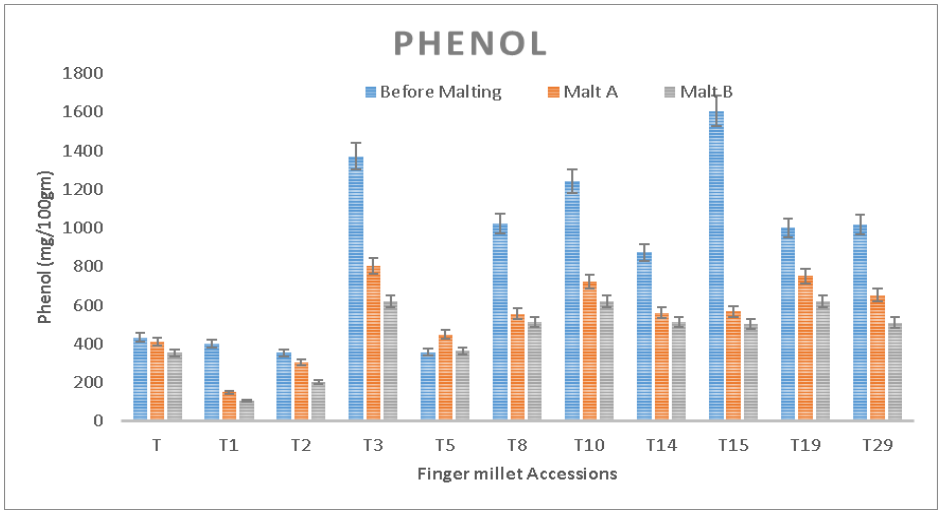

Figure 4(a): Effect of Malting on Phenol content.

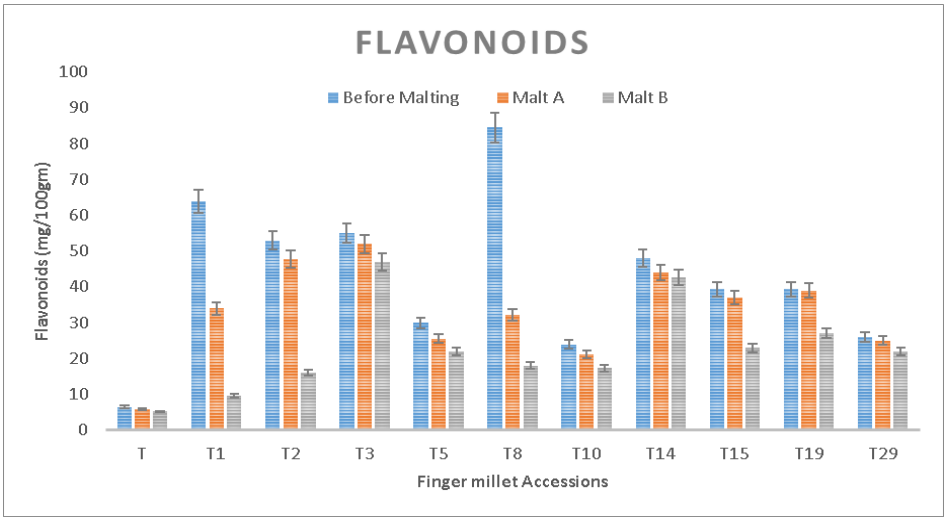

Figure 4(b): Effect of Malting on Flavonoid content.

With the increase in germination time, antioxidant activity reduces gradually; activity was 62%, 45% and 85% for T-2, T-3, and T-8 accession respectively. In the rest of the accessions, antioxidant activity shows a decreasing trend. We could not find any relation between phenolic acid content and antioxidant activity in T2, T3, T5 and, T29 accessions. Hejazi and Orsat (2016) reported the existence of a linear correlation between phenol content and antioxidant activity. Rao and Muralikrishna (2002) found higher antioxidant activity of the free phenolic acid mixture compared to that of the bound phenolic acid mixture in malted finger millet.

The changes in the antioxidant activity could thus be attributed to the total phenolic content, released minerals, and other organic compounds with an antioxidant effect. The finding supports the fact that a high total phenolic content does not necessarily translate into high antioxidant activity, but is a result of a synergy between total phenols, released organic components, and minerals with antioxidant properties.

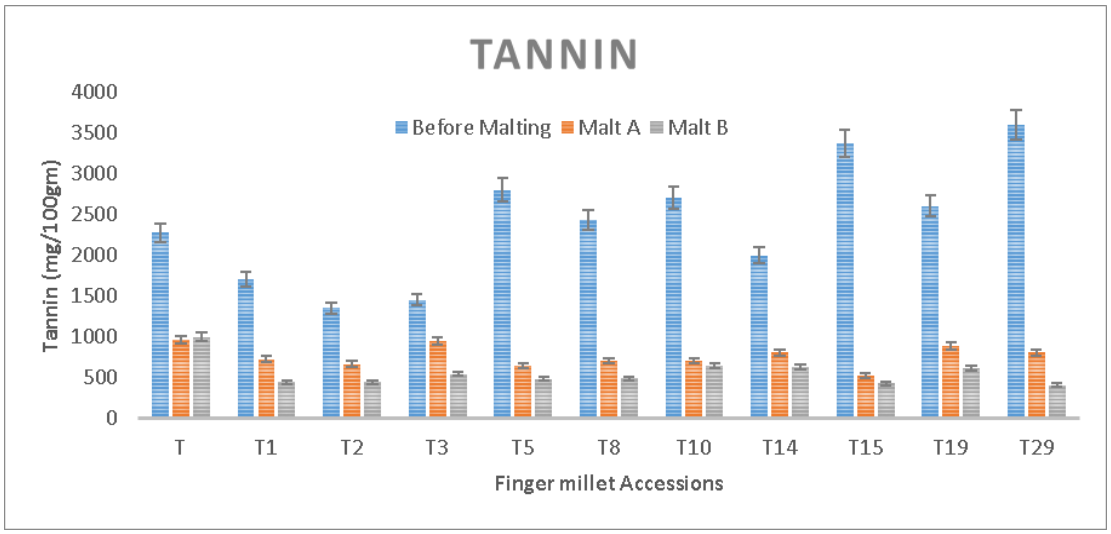

Fig.5 (a): Effect of Malting on Tannin content.

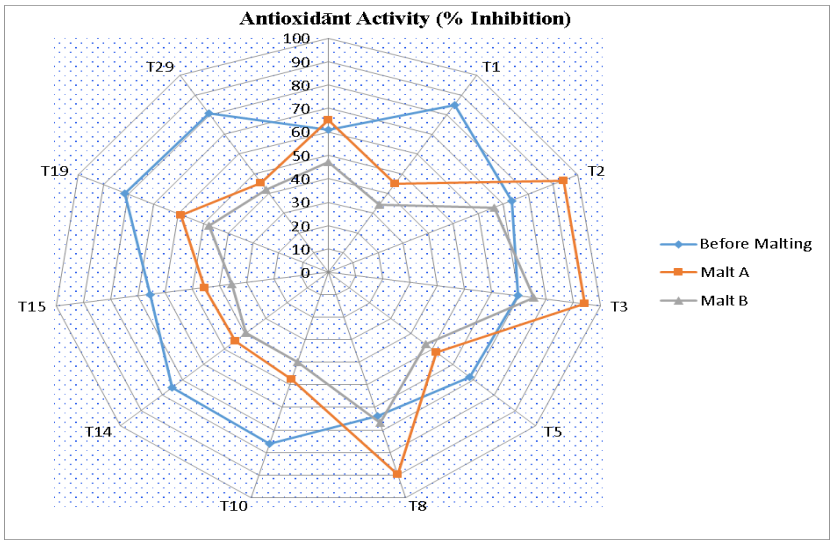

Fig. 5 (b): Changes in Antioxidant activity in Finger millet Malt.

4. CONCLUSION

Malting is one of the simple bioprocessing methods which can be used for enhancement of nutritional quality and antioxidant activity of malt. It can be used to produce nutritional malt products to overcome nutritional deficiencies, increase bio-availability and source of anti-oxidants. Standardization is needed as a longer duration of malting does not show a significant impact on nutritional qualities. The 24 hours malt was found to be significant in terms of enhancement of nutritional components and reduction of phenolic and tannin contents. The present studies show that white grains and brown grains showed a similar response to malting conditions.

Acknowledgment

The authors thanks to Principal, H.P.T. Arts, and R.Y.K. Science College, for providing all the required facilities. One of the authors (T.K.) thanks University Grants Commission, New Delhi, India for Financial assistance under Maulana Azad National Fellowship (MANF-2015-2017-MAH-54464). The authors are also

thankful to Dr. Ramnath Jagtap, CEO of *Krishidoot Bio-herbals*, for providing the laboratory facilities to carry out work and for his kind support.

5. REFERENCES

[1] Gunashree, B.S.,Selva, R.K., Roobini,R.,& Venkateswaran, G.(2014). Nutrients and antinutrients of ragi and wheat as influenced by traditional processing. *International Journal of Current Microbiology and Applied Science*, 3, 720–736.

[2] Mohammed, E. A, Ahmed, I. A. M. & Babikar, E. E. (2011). Preservation of millet flour by refrigeration, changes in total protein and amino acid composition during storage. *World Academy of Science and Engineering Technology*, **52,** 11-4.

[3] Pawar, P. A. & Dhanvijay, V.P. (2007). Weaning foods: An overview. Beverage *Food World* **34**(11), 27-33.

[4] Auti S. G., Kazi, T. & Ahire, D. D. (2017). Morpho - agronomic diversity in *Eleusine coracana* (L.) Gaertn. landraces from Maharashtra State (India). *Journal of Scientific Agriculture*, **1**, 54-61.

[5] Kazi, T. & Auti, S. G. (2017). Screening of higher mineral containing finger millet landraces from Maharashtra. *International Journal of Food Science and Nutrition*, **2**(3), 21-25.

[6] Nelson, N. (1944). Photometric adaptation of the Somogyi method for the determination of blood glucose. *Journal of Biological Chemistry* **153,** 375 – 380.

[7] Ghosh A. K., Bhargava S. N. and R. N. Tandon (1966). Studies on fungal diseases of some tropical fruits. VI. Post infection change in ascorbic acid contents of mango and papaya. *Indian Phytopath*; **19,** 262-266.

[8] Farkas, G.L. & Kiraly, Z. (1962) Role of phenolic compound in the physiology of plant diseases and disease resistance. *Phytopathologische Zeitschrift*, **44,** 105-150.

[9] Chang C., Yang M., Wen H. and J. Chern (2002). Estimation of total flavonoids content in *Propilis* by two complementary colorimetric methods. *Journal of Food Drug Analysis*, **10**, 178-182.

[10] Pearson, D. (1976). *The Chemical Analysis of Foods*, 7th Ed. Churchill Livingstone. Edinburgh. 9-13.

[11] Blois, M. S. (1958). Antioxidant determinations by the use of a stable free radical, *Nature*, **26,** 1199-1200.

[12] Mbithi, M. Van Camp, S., Yiru, J. & Huyghebaert, Y. (2000). A Nutrient and Antinutrient Changes in Finger Millet (*Eleusine coracana*) During Sprouting. *Food Science and Technology*. **33**, 9-14.

[13] Ogbonna, A. C. (2011). Current developments in malting and brewing trials with sorghum in Nigeria: A Review. *Journal of Institute of Brewing*, **117,** 394-400.

[14] Bhathal, S., & Kaur, N. (2015). Effect of germination on nutrient composition of gluten free Quinoa (*Chenopodium* quinoa). *International Journal of Scientific Research*, **4**, 423–425.

[15] Chavan, J. K. & Kadam, S. S. (1989). Nutritional improvement of cereals by sprouting. Critical Review. *Food Science and Nutrition*, **28**, 401-437.

[16] Malleshi, N. G. & Desikachar, H. S. R. (1986). Nutritive value of malted millet flours. *Plant Foods Human Nutrition*, **36,** 191-196.

[17] Saleh, A. S., Zhang, Q., Chen, J., & Shen, Q. (2013). Millet Grains: Nutritional Quality, Processing, and Potential Health Benefits. *Comprehensive Reviews in Food Science and Food Safety*, **12**(3)**,** 281-295.

[18] Swami, S. B., Thakor, N. J., & Gurav, H. S. (2013). Effect of soaking and malting on finger millet (Eleusine coracana) grain. *Agricultural Engineering International: CIGR Journal*, **15**(1), 194-200.

[19] Laxmi, G., Chaturvedi, N. & Richa, S. (2015). The Impact of Malting on Nutritional Composition of Foxtail Millet, Wheat and Chickpea. *Journal of Nutrition and Food Science*, **5,** 407-410. doi:10.4172/2155-9600.1000407

[20] Vidyavati, H., Mustai, B. J., Vijayakumari, J., Gokaki, S. & Shemshad, B. (2004). Utilization of finger millet in the preparation of papad. *Journal of Food Science and Technology*, **41(**4), 379-382.

[21] Nomura, T., Kona,Y. & Kazawa, A., T. (1969). Enzymatic mechanism of starch breakdown in germinating rice seeds II. Scuttelum as the site of sucrose synthesis. *Plant Physiology*, **44**, 765-771.

[22] Mulimani,V. H. & Supriya, D. (1993). Alpha amylase inhibitors in sorghum. *Plant Foods for Human Nutrition*, **44**, 261- 266.

[23] Glennie, C. W. (1983). Polyphenol changes in sorghum grain during malting. *Journal of Agriculture and Food Chemistry*, **31**, 1295-1299.

[24] Zhang, G., Xu, Z., Gao, Y., Huang, X., & Yang, T. (2015). Effects of germination on the nutritional properties, phenolic profiles, and antioxidant activities of buckwheat. *Journal of Food Science*, **80**, H1111–H1119. https://doi.org/10.1111/1750-3841.12830

[25] Veluppillai, S., Nithyanantharajah, K. & Vasantharuba, S. (2009). Biochemical Changes Associated with Germinating Rice Grains and Germination Improvement. *Rice Science*. **16**(3), 240-242.

[26] Ochanda, S. O., Onyango, C. A., Mwasaru, A. M., Ochieng, J. K., & Mathooko, F. M. (2010). Effects of malting and fermentation treatments on group B-vitamins of red sorghum, white sorghum and pearl

millets in Kenya. *Journal of Applied Biosciences* **34,** 2128– 2134.

[27] Verma, V. & Patel, S. (2013). Value added products from nutria cereals: Finger millet (*Eleusine coracana*). *Emirates Journal of Food and Agriculture*, **25(**3), 169- 176.

[28] Banhegyi, G., & Mandl, J. (2001). The hepatic glycogenoreticular system. *Pathology and Oncology Research*, **7**, 107–110. https://doi. org/10.1007/BF03032575

[29] Desai, D., Kulkarni, S. S., Sahu, A. K., Ranveer, R.C. & Dandge, P. B. (2010). Effect of supplementation of malted *Ragi* flour on the nutritional and sensorial quality characteristics of cake. *Advanced Journal of Food Technology*, **2**, 67-71.

[30] Abdelrahaman, S. M., Elmaki, H. B., Idris, W. H., Hassan, A. B., Babiker, E. E., & El Tinay, A. H. (2007). Antinutritional factor content and hydrochloric acid extractability of minerals in pearl millet cultivars as affected by germination. *International journal of food sciences and nutrition*, **58**(1), 6-17.

[31] Sripriya, G., Chandrasekharan, K., Murthy, V., & Chandra, T. (1996). ESR spectroscopic studies on free radical quenching action of finger millet (*Eleusine coracana*). *Food Chemistry*, **57**(4), 537-540.

[32] Maillard, M. N. & Berset, C. (1995). Evolution of antioxidant activity during kilning, role of insoluble bound phenolic acids of barley and malt. *Journal of Agriculture and Food Chemistry*, **43,** 1789-1793.

[33] Hithamani, G. & Srinivasan, K. (2017). Bioaccessibility of polyphenols from selected cereal grains and legumes as influenced by food acidulants. *J. Sci. Food Agric*. **97**(2), 621-628. doi:10.1002/jsfa.7776

[34] Udeh, H. O., Duodu, K. G., & Jideani, A. (2018). Malting Period Effect on the Phenolic Composition and Antioxidant Activity of Finger Millet (*Eleusine coracana* (L.) Gaertn.) Flour. *Molecules (Basel, Switzerland)*, **23**(9), 1-12. doi:10.3390/23092091

[35] Gunashree, B.S.,Selva, R.K., Roobini,R.,& Venkateswaran, G.(2014). Nutrients and antinutrients of ragi and wheat as influenced by traditional processing. *International Journal of Current Microbiology and Applied Science*, **3**, 720–736.

[36] Onyango, C. A., Ochanda, S. O., Mwasaru, M. A., Ochieng, J. K., Mathooko, F. M., & Kinyuru, J. N. (2013). Effects of malting and fermentation on anti-nutrient reduction and protein digestibility of red sorghum, white sorghum and pearl millet. *Journal of Food Research*, **2**, 41–49. https://doi.org/10.5539/jfr.v2n1p41

[37] Butler, L. G., Riedl, D. J., Lebryk, D. G. & Blytt, H. J. (1984). Interaction of proteins with sorghum tannin: mechanism, specificity and significance. *Journal of American Oil Chemist's Society,* **61,** 916-920.

[38] Hejazi, S. N., & Orsat, V. (2016). Malting process effects on antioxidant activity of finger millet and amaranth grains. *Journal of Food Research*, *5*(1), 1-17.

[39] Rao Subba, M. V. S. S. T. & Muralikrisna, G. (2002). Evaluation of the antioxidant properties of free and bound phenolic acids from native and malted finger millet (Ragi, *Eleusine coracana* Indaf – 15). *Journal of Agriculture and Food Chemistry* **50,** 889 – 892.