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Original Research

Effect of pre-treatment on health enhancing bioactive compounds and functional properties of improved Assosa I sorghum flour variety cultivated in Ethiopia

Ebisa Olika Keyata [1*], Yetenayet B. Tola[2], Geremew Bultosa[3]& Sirawdink Fikreyesus Forsido[2]

[1]Department of Food and Nutritional Sciences, Wollega University, P.O. Box 38, Shambu, Ethiopia
[2]Department of Post-Harvest Management, Jimma University, College of Agriculture and Veterinary Medicine, P.O. Box: 307, Jimma, Ethiopia
[3]Department of Food Science and Technology, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana

Abstract

This study assessed the effects of washing, soaking, and malting on the functional characteristics and phytochemical composition of the improved Assosa I sorghum variety, which is grown in the Benishagul Gumuz Region of Ethiopia. The experiment had only one component (pre-treatment), and it was conducted with four levels (raw, washed, soaking, and malted) in a properly randomized fashion. The findings demonstrated that malting significantly ($p < 0.05$) raised the flour's phytochemical content and antioxidant capability among the four treatment levels that showed ($p < 0.05$) decrease in bulk density and swelling power, despite increases in solubility, water, and oil absorption capacity. Antioxidant capacities, the IC50 of DPPH, and ferric-reducing antioxidant power (FRAP) were linked with levels of total phenolic, flavonoids, L-ascorbic acid, and β-carotene. Overall study results showed that malting had the greatest potential to increase, relative to the control sample, the antioxidant power of total phenolic, total flavonoid, β-carotene, L-ascorbic acid, 1,1-diphenyl-2-picrylhydrazyl, and ferric reductions by 122.86, 120.18, 54.55, 29.01, 7.11, and 36.63%, respectively. Malting also increases solubility by 51.94% and reduces bulk density by 7.25% when applied to raw sorghum. The creation of supplemental weaning foods for infants and young toddlers could greatly benefit from these findings.

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*Corresponding Author:
Ebisa Olika Keyata

E-mail:
ebisaolika20@gmail.com

INTRODUCTION

A major source of nourishment for humans, cereal grains have seen a steady rise in production to keep up with the growing global population (Saleh et al., 2019). Cereal grains include elements that have been demonstrated to improve human health, such as antioxidants and anti-disease agents (Ed Nignpense et al., 2021).

In the semiarid regions of the world, sorghum (Sorghum bicolor L.), a crop that can resist drought, is a major source of food. It is the sixth most planted crop worldwide and the second most farmed cereal grain in Africa, according to Zhao et al. (2019). Furthermore, commercial processing accounts for less than 5% of the annual production of sorghum, a gluten-free cereal grown primarily as a food crop in various African countries (Okoli et al., 2010).

Sorghum is the third most important cereal crop in Ethiopia, behind teff and maize (CSA, 2019). A mainstay of the diet, it is pounded into flour and utilised in many different recipes, including bread, porridge, nifro (muulu), injera, baby food, syrup, and local beverages known as "tella, faarso" and "arekie, araaqe" (Tasie & Gebreyes, 2020). In addition, some researchers have stated that sorghum grains are acknowledged as a vital source of bioactive chemicals and dietary antioxidants (de Morais Cardoso et al., 2017; Singh et al., 2019). Bioactive compounds derived from sorghum have been reported by multiple authors to improve gut health and reduce the risk of non-communicable and chronic diseases such as hypertension (Moraes et al., 2012), diabetes (Kim & Park, 2012), obesity (Chung et al., 2011), and gastrointestinal cancer (Yang et al., 2009).

Sorghum is a major grain in the Benishangul-Gumuz Region (BGR), one of western Ethiopia's main sorghum-producing regions (CSA, 2019). Among the sorghum varieties farmed in the area, the Assosa I variety was selected for this study because it is widely used and well-liked by producers and users (Legesse et al., 2019).

To enhance the minerals' bioavailability, boost sorghum's utilisation and consumption, and employ the processed flour as a component in food product developments, sorghum grains must be pretreated before being ground into flour (Ogbonna et al., 2012). Depending on the type of processing procedures used on the grain, the pre-treatments given to the sorghum grains may improve or reduce the phytochemical contents and antioxidant capacity (Xiong et al., 2019). There is little information available on the effects of pre-treatments including washing, soaking, and malting on the phytochemical composition, antioxidant capacity, and functional characteristics of the Assosa I sorghum grain variety, which is cultivated in Ethiopia's Benishangul Gumuz region. Thus, the effects of pre-treatments on the phytochemical contents, antioxidant capacity, connection between phytochemicals and antioxidants, and functional features of the Assosa I sorghum grain variety were described in this paper.

MATERIALS AND METHODS

Experimental Material

Ethiopia's Assosa Agricultural Research Centre (AARC) provided the experimental sample. To clean the grains, all dockages—foreign debris, broken, and damaged seeds—were physically removed.

Experimental Design

The study used a completely randomised design (CRD), in which the single factor—pre-treatment of sorghum grain—was repeated four times at distinct stages (raw, washed, soaking, and malted). The inquiry comprised twelve experimental units.

Pre-treatment techniques

The pre-flour treatments used in this investigation were performed in accordance with Bekele *et al*. (2012).

Control (unprocessed sorghum)

Following cleaning, 500 grams of the unprocessed sorghum grains used for control were directly ground into flour.

Washing

The 500 grams of cleaned sorghum grains were cleaned three times in 1500 mL of tap water (pH

= 6.8, 25 ^{o}C), and then they were dried for twenty-four hours at 50 ^{o}C.

Soaking

Using a sorghum tap water ratio of 1:5, w/v, 500 g of cleaned sorghum grain samples were steeped for six hours at 25˚C in a steeping vessel with 0.2% NaOH solution for the soaking process. Prior to the soaking procedure, the samples underwent three rounds of washing. The vessel was emptied and filled with fresh tap water at room temperature after six hours. After then, the water was emptied and replenished every three hours for the next eighteen hours, with an air break of one hour in between. After steeping, the grains were dried in an oven (DHG-9203A, Shanghai, China) at 50˚C for a whole day.

Malting

After first steeping for six hours in a 0.2% NaOH solution, 500 g of sorghum grains were malted. Over the course of the next eighteen hours, the water was drained and refilled every three hours, with an hour's air rest in between (Bekele et al., 2012; Keyata et al., 2021a). The soaked grains were left to germinate at room temperature for forty-one hours after the preliminary test. A hygrometer (Model AB167, West Germany) was used to measure the relative humidity (RH), which was kept at 95% by using a hand sprayer to apply 20 mL of distilled water twice a day. To keep the roots and shoots from meshing, the germinating grains were rotated on a regular basis. Next, the malted grains were dried for 24 hours at 50 degrees Celsius in an oven. Next, a 0.5 mm filter size was used to grind the dried malted seeds (AACC, 2000). Until it was time for analysis, the flour was stored at 4˚C, wrapped in aluminium foil, and put in heavy-duty polyethylene bags that were airtight and moisture-proof.

Determination of phytochemical composition and antioxidant capacity

Using the maceration technique, Keyata et al. (2021b) determined the phytochemical content (TPC, TFC, beta carotene, and L-ascorbic acid) and antioxidant capacity (DPPH and FRAP) of milled sorghum samples. 100 millilitres of 99.8% methanol were used to soak 100 milligrammes of ground material, yielding a concentration of about 1 milligramme per millilitre. After soaking in the solvents for a full day, the samples were agitated in a mechanical shaker at room temperature and filtered through filter paper.

The absorbance was then measured at 765, 510, 450, 517, and 593 nm, respectively, and total phenolic, total flavonoid, beta carotene content, DPPH, and FRAP were calculated using a UV-VIS spectrophotometer in accordance with Keyata et al. (2021b). The extract concentration that provides 50% of radical scavenging activity (IC50) was found using the DPPH graph pattern (percentage of inhibition vs. extract concentration) (Burits & Bucar, 2000). While Keyata et al. (2021b) outline the 2, 6-dichloroindophenol titration methods (AOAC 2007, method 967.21) were used to measure the L-ascorbic acid level.

Functional properties of the flour

Functional properties such as bulk density, water and oil absorption capacity, solubility, and swelling power were determined according to procedures described by Keyata *et al*. (2021b).

Statistical analysis

SAS version 9.3 was used for all statistical analyses, and a difference of $p < 0.05$ was deemed significant. To find significant differences between means ($p < 0.05$), mean comparison tests were conducted using Fisher's least significant difference (LSD). The results were indicated as mean + standard deviation. Pearson's correlation was used to evaluate the association between bioactive compounds and antioxidant capacity. Evans (1996) categorized the correlation strengths as follows: r = 0.00-0.19 = "very weak", r = 0.20-0.39 = "weak", r = 0.40-0.59 = "moderate", r = 0.60-0.79 = "strong", and r = 0.80-1.0 = "very strong".

RESULTS AND DISCUSSION

Health-enhancing bioactive compounds

In order to detoxify dangerous and detrimental oxidants, bioactive substances are essential (Praveena & Estherlydia, 2014). Table 1 displays how the pre-flour treatment affected the sorghum grain samples' total flavonoid, total phenolic, β-carotene, and L-ascorbic acid levels.

The total phenolic content (TPC) of the sorghum grain samples was significantly ($p < 0.05$) affected by pre-flour treatments, according to the results. The TPC values for the sorghum grain flour that had been uncooked, cleaned, soaked, and malted were 3.5, 3.4, 2.8, and 7.8 mg GAE/g (db), in that order. Comparing the malted sorghum grains to the control sorghum grains, the results showed that the TPC of the former had increased by more than double. Corn, wheat, and barley grains were also shown to have higher TPC in the grain malting sample (Niroula et al., 2019). This may result from the degradation of lignin and other cell wall polymers, which can release phenolic chemicals, as well as lignin production during germination (Kim et al., 2018). When compared to the control sorghum grains, the TPC in the washed and soaked sorghum was considerably ($p < 0.05$) lower at 3.97 and 19.83%. Similar TPC reductions, ranging from 21.97 to 28.30%, were found for Egyptian soaked grain sorghum types (Afify et al., 2012a). The leaching of phenolic compounds into the soaking water may be the cause of the TPC loss in the sorghum grains after they have been washed and soaked.

The components of plant phenols known as flavonoids exhibit a variety of health benefits and play a critical role in illness prevention (Tiwari & Husain, 2017). The total flavonoid content (TFC) of the treated sorghum grain flour, untreated sorghum grains, and control group differed significantly ($p < 0.05$). The TFC in the flour made from washed, soaked, malted, and unprocessed sorghum grains was 1.09, 0.82, 0.65, and 2.4 mg CE/g, in that order. The TFC had dramatically ($p > 0.05$) dropped by 24.77% and 40.37%, respectively, from the soaked and washed grain samples. In this investigation, compared to the control sample and other pre-treated procedures, malting had enhanced the TFC by more than two times. Farooqui et al. (2018) also showed an increase in TFC on malting of barley grains (0.29 to 0.37 mg CE/g). Similar findings were made by Khyade and Jagtap (2016) about chickpea grains (0.97 to 1.23 mg/g), cowpea grains (1.03 to 2.11 mg/g), and black grammes grains (1.10 to 1.79 mg/g).

The most powerful precursor of vitamin A, beta (β)-carotene functions as an antioxidant that lowers the risk of heart disease, stroke, and several types of cancer. Additionally, according to Gul et al. (2015), it can strengthen the immune system and offer defence against age-related macular degeneration, which results in irreversible blindness in adults. The amount of β-carotene in unprocessed sorghum grain control and washed sorghum grain did not differ significantly ($p > 0.05$). Between the soaked and malted sorghum grains and the unprocessed grain control, there was a significant difference ($p < 0.05$). The outcome demonstrates that although the soaking sample had a decline of more than thrice, malting boosted the β-carotene content of the sorghum by 48.25%. Khyade and Jagtap (2016) observed a comparable rise in β-carotene levels during the sprouting stages of cowpea, chickpea, and black grammes (42.62 to 57.05 µg/100 g, 159.88 to 221.05 µg/100 g, and 14.071 to 21.05 µg/100 g, respectively). According to Yang et al. (2001), there was a considerable rise in β-carotene concentration in wheat as the germination period rose. According to the study, one effective way to increase the amount of β-carotene in cereal grains is by malting them.

For the formation of collagen, L-ascorbic acid is a co-factor that is required in the diet, along with catecholamines, L-carnitine, amino acids, and some peptide hormones. Between raw and processed sorghum, there was a significant difference ($p < 0.05$) in the amount of L-ascorbic acid. The findings showed that the L-ascorbic acid content in malted sorghum grains rose by 29.13%. Laxmi et al. (2015) observed that malting foxtail millet, wheat, and chickpea grains resulted in a comparable rise in L-ascorbic acid content. L-ascorbic acid content in malted soybean was also shown to have increased twofold, according to Lien et al. (2017). The enzymatic breakdown of starch by amylases and diastases, which increases glucose availability for the production of vitamin C, may be the cause of the increase in L-ascorbic acid during malting (Nkhata et al., 2018). In the same period, after soaking sorghum grains in water for eighteen hours, L-ascorbic acid reduced by more than three times. This can be the result of the soaked water absorbing L-ascorbic acid.

Table 1

Effect of pre-treatments (washing, soaking and malting) of on bioactive compounds of improved Assosa I sorghum grain variety

Pre-treatments	TPC (GAEmg/g)	Improved (%)	TFC (CEmg/g)	Improved (%)	β-carotene (mg/100 g)	Improved (%)	L-AAC (mg/100 g)	Improved (%)
Control	3.5 ± 0.1^{b}	-	1.09 ± 0.05^{b}	-	1.1 ± 0.1^{b}	-	13.1 ± 0.7^{b}	-
Washed	3.4 ± 0.1^{b}	NI	0.82 ± 0.05^{c}	NI	1.0 ± 0.1^{b}	NI	8.6 ± 0.4^{c}	NI
Soaked	2.8 ± 0.2^{c}	NI	0.65 ± 0.09^{d}	NI	0.45 ± 0.08^{c}	NI	4.1 ± 0.3^{d}	NI
Malted	7.8 ± 0.2^{a}	122.86	2.4 ± 0.1^{a}	120.18	1.7 ± 0.1^{a}	54.55	16.9 ± 0.6^{a}	29.01
CV	3.92		5.39		8.54		4.55	
LSD	0.34		0.13		0.18		0.97	

Control = unprocessed sorghum grains, TPC: total phenolic, TFC: total flavonoid content, β-carotene: beta carotene, AAC: ascorbic acid content. Means with different letters across a column are significantly different. NI: Not improved

In vitro antioxidant capacity

The percentage of DPPH radical scavenging activity at 0.43 mg/mL, inhibition concentrations (IC50) of DPPH radical scavenging at various concentrations (0.2 to 0.56 mg/mL), and ferric ion reducing antioxidant potential (FRAP) at 2 mg/mL of control untreated sorghum and pre-treated sorghum grain samples are provided in Table 2 to show the impact of pre-treatment techniques on antioxidant capacity.

The outcome showed that there was no significant ($p > 0.05$) difference in the IC50 values of raw and washed sorghum. In comparison, the IC50 values of the untreated control sorghum grains (0.33 mg/mL), soaked sorghum grains (0.39 mg/mL), and malted sorghum grains (0.26 mg/mL) varied substantially ($p < 0.05$). The results of the study indicate that malted sorghum grains performed better and had greater antioxidant capacity because their IC50 was found to be lower than that of other pretreatment procedures and control untreated sorghum grains. When compared to the other grain pre-treatment methods that were examined, the soaked grains exhibited the lowest antioxidant capacity. Reduced antioxidant capacity in soaking white sorghum grains was found by Afiffy et al. (2012). It was demonstrated by Xu and Chang (2008) that soaking green peas, yellow peas, and lentils in water decreased their antioxidant capacity. The leaching of flavonoids and phenolics from the water may be the cause of the decreased antioxidant levels during soaking. The activation of polyphenol oxidase enzymes during malting may be the cause of the increased antioxidant capacity. Wheat grains were also found to exhibit a comparable rise in antioxidant capacity during malting (Van Hung et al., 2011).

At a concentration of 0.43 mg/mL, the pre-treatment methods of sorghum grains had a significant ($p < 0.05$) influence on the percentage inhibition of free radicals. The percentage DPPH value at 0.43 mg/mL for the washed, soaked, malted, and control unprocessed sorghum grains was 59.56%, 56.46%, 52.54%, and 63.95%, in that order (Figure 1). The outcome demonstrated that while soaked sorghum grains had reduced DPPH radical scavenging capabilities, malted sorghum grains had a greater capacity to do so. According to Sing et al. (2019), leaching in the soaking solution resulted in a drop in TPC, TFC, L-ascorbic acid, β-carotene, tannins, and phytate in the soaked sorghum grains, whereas the activation of endogenous enzymes caused an increase in malting. Im Chung et al. (2016) showed a comparable rise in the DPPH radical scavenging activity of rice malting. At the same dose, the antioxidant capacity for BHT (73.97%) and L-ascorbic acid (78.99%) in the control and pre-treated sorghum samples was found to be lower than that of the standard positive control.

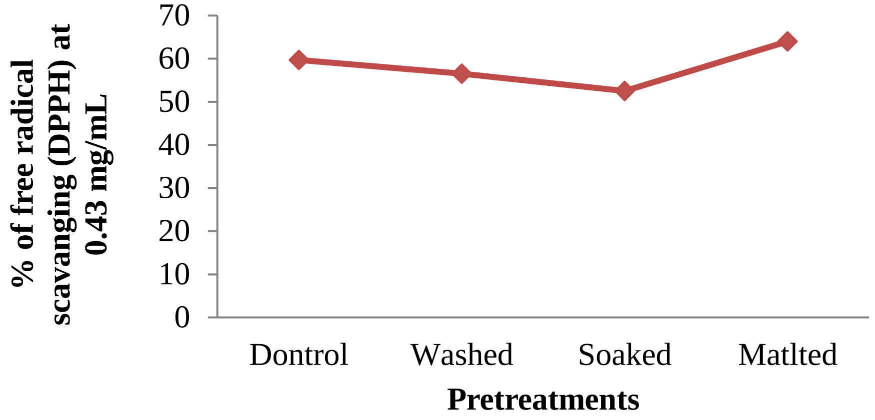

Figure 1 Percentage *of free radical scavenging activities of methanolic extract of pretreatments of improved Assosa I sorghum grain variety*

At a dosage of 2 mg/mL, there was a significant ($p < 0.05$) difference in the ferric reducing antioxidant power (FRAP) between the pre-treated and untreated sorghum grain samples. According to the results, soaking sorghum had a lower FRAP (37.29 mM Fe2+/g), which is next to wash sorghum grains (49.74 mM Fe2+/g). Malted sorghum grains had a greater FRAP value (73.56 mM Fe2+/g), followed by the control sample (53.87 mM Fe2+/g). A notable enhancement in the FRAP value was also found for malted rice grains (Chinma et al., 2015). Pre-treatment methods included the use of cell wall-degrading enzymes that are active during the malting process to modify the cell wall of the malted sorghum grains. This alteration released bound phenols and enhanced the grains' antioxidant capabilities (Kadiri, 2017). As a result, because malted sorghum grains can prevent free radicals and improve human health, they can be regarded as a necessary component for product development.

Table 2

Effect of pre-treatments (washing, soaking and malting) on antioxidant capacity of improved Assosa I sorghum grain variety

Preflour treatments	IC_{50} (mg/mL)	%DPPH (0.43mg/mL)	Improved (%)	FRAP (mM of $Fe^{2+/}$g)	Improved (%)
Control	0.33 ± 0.02^{b}	59.7 ± 1.0^{b}	-	53.87 ± 1.15^{b}	-
Washed	0.35 ± 0.016^{b}	56.5 ± 1.7^{c}	NI	49.7 ± 0.9^{c}	NI
Soaked	0.39 ± 0.02^{a}	52.5 ± 2.1^{d}	NI	37.3 ± 1.6^{d}	NI
Malted	0.26 ± 0.02^{c}	63.95 ± 0.36^{a}	7.11	73.6 ± 0.8^{a}	36.63
CV	7.00	2.83		2.00	
LSD	0.05	3.29		2.14	

Control = unprocessed sorghum grains, Means with different letters across a column are significantly different. NI: Not improved

Correlation between antioxidant capacity and phytochemical contents

Table 3 displays the Pearson's correlation coefficient between the antioxidant capacity (% DPPH, IC50, and FRAP) and phytochemical contents (TPC, TFC, β-carotene, and L-ascorbic acid concentrations) for the control unprocessed sorghum grains, washed, soaked, and malted sorghum grains. The percentage of DPPH scavenging activity of the TPC (r = 0.87) and TFC (r = 0.91) exhibited a high positive association with a non-significant difference ($p > 0.05$). For triticale grains, a comparable high and positive connection between TPC and DPPH scavenging activity was observed (Kruma et al., 2016). The results showed that there was a strong positive correlation (r = 0.996) and a significant ($p < 0.01$) relationship between the DPPH and the levels of L-ascorbic acid and β-carotene, respectively (r = 0.987 and 0.987). The IC50 of DPPH exhibited a substantial ($p < 0.05$) and robust negative association with the contents of TFC (r = -0.964), β-carotene (r = -0.986), and L-ascorbic acid (r = -0.964). This is because the concentration needed to obtain the IC50 decreased as these chemical quantities increased. The results showed that there was a substantial ($p < 0.05$) and strong positive connection (r = 0.958) between the FRAP and the concentrations of TFC, β-carotene, and L-ascorbic acid (r = 0.96). The greater the FRAP, the higher the concentration of these nutrients.

Table 3

Correlation between bioactive compounds (total phenolic, total flavonoids, beta-carotene and L-ascorbic acid) and antioxidant capacity

Phytochemical parameters	Antioxidant capacity		
	%DPPH(0.43mg/mL)	IC50 of DPPH	FRAP
Total phenolic content	0.87(0.13)	-0.94(0.06)	0.94(0.06)
Total flavonoid content	0.91(0.09)	-0.964(0.035)	0.958(0.042)
Beta-carotene content	0.987(0.013)	-0.986(0.014)	0.99(0.01)
Ascorbic acid content	0.996(0.004)	-0.964(0.036)	0.96(0.04)

Numbers between brackets correspond to the p-value of the Pearson test

Functional Properties

Table 4 displays the bulk density, oil absorption capacity, water absorption capacity, swelling power, and solubility of the pre-flour treated and control untreated sorghum grains.

The bulk density (BD) of sorghum flour was considerably ($p < 0.05$) decreased by pre-treatment processes, which included malting, washing, and soaking of grains, respectively, by 7.25 percent, 8.70 percent, and 14.49 percent. On sorghum grain flour, comparable BD decreases of 4%, 5%, 11%, 14%, and 21% were observed during germination of the first, second, third, fourth, and fifth days (Abd Elmoneim & Bernhardt, 2010). Additionally, the lowering of BD for malted green gramme, cowpea, lentil, and Bengal gramme grain flours was observed by Ghavidel and Prakash (2006). The disintegration of complex components like proteins and carbohydrates is the reason for the decline in BD (Ocheme et al., 2015).

High BD cereal grain flour has drawbacks when it comes to ingestion, especially in terms of nutrition, as a small amount can result in extremely thick porridge or grain with little nutrients. Conversely, in order to get the same viscosity, additional less dense flour will be needed (Wilhelm et al., 2004). As a result, every pre-treatment method examined in this study demonstrated a drop in BD, which is crucial for creating weaning and supplemental meal compositions.

Particularly when managing dough in food compositions, water absorption capacity, or WAC, is essential (Iwe et al., 2016). The flour made with malted sorghum grains had the highest WAC value ever measured (1.40 g/g). The increase in WAC up during malting could be attributed to the breakdown of polysaccharide molecules, which would increase the number of sites for water contact and retention. Increased water absorption capacity reduces viscosity and improves a product's softness, bulkiness, and consistency (Oyarekua & Adeyeye, 2009).

Malted sorghum grain flour saw a rise in WAC from 1.30 to 1.40 g/g. Siddiqua et al. (2019) showed a comparable increase in WAC with malting in maize (1.27 to 1.91 g/g), sorghum (1.18 to 2.06 g/g), and wheat (0.5 to 0.93 g/g). A comparable rise in the WAC was also noted in another investigation on maize grain malting (Gernah et al., 2011). The WAC reported for rice grain flour (1.92 g/g) was higher than the values obtained for both the pre-flour treated sorghum grains and the control untreated sorghum grains (Modipuram, 2013). For creating thinner gruels for babies and small children, malted sorghum with a lower WAC is appropriate.

Pre-treatment methods considerably ($p < 0.05$) increased the oil absorption capacity (OAC) of the untreated control sorghum grains, with the exception of the washed sorghum grains. The OAC of the soaked and malted sorghum grains did not change significantly ($p > 0.05$), whereas the untreated, control sorghum grains did differ significantly ($p < 0.05$). Malted sorghum grains yielded the highest OAC (1.29 g/g), whereas untreated, control sorghum grains yielded the lowest OAC (1.10 g/g). The solubilization and dissociation of protein, carbohydrates, and other cell wall components during malting may encourage strong oil binding, which could account for the increased OAC found in malted sorghum grains (Agrawal et al., 2013). Similar results were seen for maize cultivated in Bangladesh (1.07 to 1.39 g/g) and malted sorghum grains grown in Nigeria (1.03 to 1.18 g/g) (Ocheme et al., 2015). (Siddiqua et al., 2019). The increased OAC found in malted sorghum grains is crucial for enhancing the flavor, lipophilicity, and taste of food products.

The pre-treated and control untreated sorghum grains' swelling power (SP) ranged from 3.7 to 5.3 g/g, and it significantly ($p < 0.05$) decreased after the grains were processed. The untreated control sorghum grain sample had the highest SP (5.3 g/g), whereas the malted sorghum grain sample had the lowest SP (3.7 g/g). The grain samples of soaked and malted sorghum did not differ in a way that was statistically significant ($p > 0.05$). Comparable to the findings of Siddiqua et al. (2019), malted maize grains showed a decrease in SP (4.2 to 4.0 g/g). Nefale and Mashau (2018) also demonstrated a considerable drop in finger millet SP (4.83 to

3.17 g/g) following malting. A low swelling index may be the outcome of a high amylose concentration, according to Adebowale et al. (2005).

According to Adepeju et al. (2014), solubility is the quantity of water-soluble materials in a sample per unit weight. Malted sorghum grain flour had the highest solubility (37.3%), whereas untreated sorghum grain flour had the lowest solubility value (24.55%). The results demonstrated that pre-treatment methods improved the solubility of components of sorghum grain flour in washed, soaked, and malted sorghum grains by 24.32%, 36.42%, and 51.89%, respectively. When comparing the solubility of malted sorghum grains to other pre-treatment methods and untreated sorghum grains, there was a significant ($p < 0.05$) difference. Obadina et al. (2017) showed comparable increases in the solubility of malted pearl millet grain flour. The breakdown of polysaccharides into monosaccharides during germination may be the cause of the improved solubility in malted sorghum grain flour (Pal et al., 2016). According to the study, malted sorghum's high solubility indicates that it may be easier to digest and produce a smooth, uniform gruel—a quality that is ideal for baby food formulations (James et al., 2018).

Table 4

Effects of pre-treatments (washing, soaking and malting) on functional properties of improved Assosa I sorghum grain variety

Pre-treatments	BD (g/mL)	Reduction (%)	WAC (g/g)	OAC (g/g)	SP (g/g)	SO (%)	Improved (%)
Control	0.69 ± 0.03^{a}	-	1.3 ± 0.1^{c}	1.1 ± 0.1^{b}	5.3 ± 0.3^{a}	24.55 ± 1.41^{c}	-
Washed	0.63 ± 0.02^{cb}	8.70	1.34 ± 0.04^{cb}	1.14 ± 0.02^{b}	4.8 ± 0.1^{b}	30.5 ± 1.4^{b}	24.24
Soaked	0.59 ± 0.02^{c}	14.49	1.38 ± 0.04^{ab}	1.26 ± 0.02^{a}	4.0 ± 0.2^{c}	33.5 ± 1.9^{b}	36.46
Malted	0.64 ± 0.01^{b}	7.25	1.4 ± 0.1^{a}	1.29 ± 0.03^{a}	3.7 ± 0.3^{c}	37.3 ± 0.9^{a}	51.94
CV	3.06		1.57	3.17	4.68	5.10	
LSD	0.039		0.04	0.08	0.42	3.20	

Control = unprocessed sorghum grains, BD: bulk density, WAC: water absorption capacity, OAC: oil absorption capacity, SP: swelling power, SO: solubility. NI: Not improved
Means with different letters across a column are significantly different.

CONCLUSIONS

The results showed that the antioxidant capacity, functional qualities, and phytochemical contents were significantly ($p < 0.05$) impacted by pre-treatment methods. Malting boosted antioxidant capacities such %DPPH, IC50, and FRAP and raised the total phenolic, flavonoid, β-carotene, and L-ascorbic acid concentrations among the pre-milling treatment procedures investigated in this work. The phytochemical composition (total flavonoids, β-carotene, L-ascorbic acid, and total phenolics) showed a good correlation with the antioxidants of the sorghum variety. Good functional qualities of malted sorghum included a decreased bulk density and an increase in solubility. Therefore, if combined with vegetables and pulses that are strong in protein and vitamins, malted Assosa i sorghum may have enormous potential in creating nutrient-dense supplementary diets for newborns and early children.

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DECLARATION

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

All data included in the article are available from the corresponding author upon request.

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