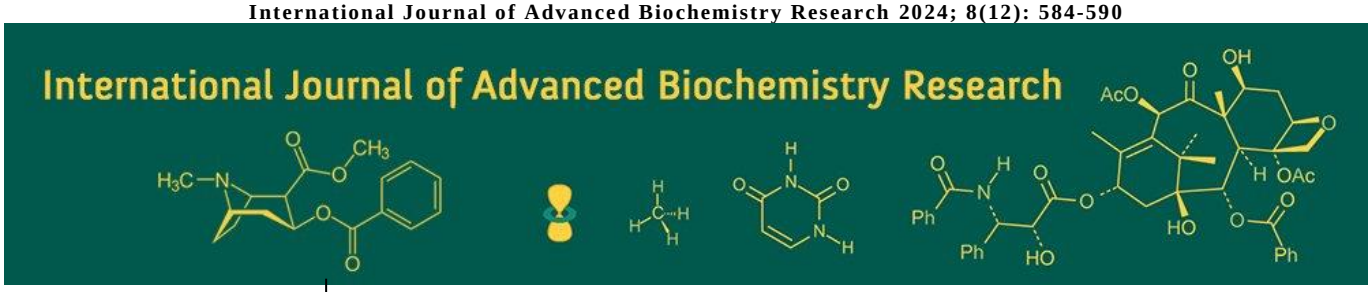

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Enhancing browntop millet grains palatability by innovative technologies and their effects on anti-nutritional and functional properties

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Abstract
Green technologies such as ultrasound (US) and High-Pressure Processing (HPP) are used for treatment of various millets and studied their impact on various properties and characteristics. However, there are no studies regarding the changes occurring in US and HPP treated whole browntop millet grains (BTM). The purpose of this study is to investigate the influence of US and HPP treatments on BTM under various treatment settings such as power, pressure, and duration, i.e., 200 & 100 W for US and 400 & 300 MPa for HPP at 5-30 min (5 min interval) for a sample to solvent ratio of 1:5 (w/v) to improve the palatable nature. Impact of these treatments on various functional and anti-nutritional properties of BTM was analyzed. Water holding capacity (WHC), oil holding capacities (OHC), solubility swelling power (SP), tannins, and phytates were assessed in treated BTM flours. US & HPP flours at 200 W for 20 min and 400 MPa for 20 mins are considered as optimal conditions because it increased the WHC from 1.43 to 1.68 and 1.84 g/g; OHC from 1.14 to 1.44 and 1.61 g/g for control, US and HPP treated flours respectively, and decreased tannins content from 110.33 to 18.23 and 33.06 mg/100 g for control, US and HPP treated flours respectively. The results suggested that US and HPP treatments on grains improved the functional properties of the BTM flour.

Keywords: Browntop millet, ultrasound, high pressure processing, functional properties, anti-nutritional properties, palatability

1. Introduction
Millets are tiny, small-seeded grass crops belonging to the family of Poaceae [1] and rich in proteins, bioactive compounds, and minerals. Also, they are superior to other major cereals (rice and wheat), and protect against degenerative diseases such as gastrointestinal disorders, cancer, and neurological concerns [2]. The word "Millet" originated from the Latin word "Milum" which means grains; They have been cultivated throughout the world for more than 10000 years [3]. Though the exact origin is unknown, but it is believed that these grains have originated in different parts of the world independently and they were among the earliest domesticated crops [1, 4]. They have remarkable facilities to survive in less fertile soil, drought situations, and are pest resistant, and can survive in harsh climatic conditions and require less time i.e., 45-60 days for harvest [5]. These grains are significant as functional ingredients for creating innovative commercially essential food items derived from their hypoglycaemic profile and bioactive content. Despite various health advantages and agro-economic possibilities, millets have fallen out of trend due to their coarse texture, which makes them unpalatable and; in industrialized nations, they are underutilized [2]. They are considered sustainable agricultural alternatives that may be required to fulfill food requirements and boost the economic status of the farmers and have been considered as a staple food due to their functional properties [5].
According to [6] millets are divided into two types based on their sizes i.e., major or large and minor or small millets. Under major millets category includes sorghum, pearl, finger, foxtail, proso millets & buckwheat; whereas minor millets category includes kodo, barnyard, browntop, little millets, & teff. Most of the millets are underutilized and among all other millets; browntop millet is more under-utilized and forgotten crop. *Urochloa ramose* L., aka browntop millet, belongs to the Polygonaceae family known as Korale or Karlakki in Karnataka, Andakorra in Andhra Pradesh, Paluppu Tinai in Tamil Nadu.

It is gluten-free and high in vital nutrients. Due to its gluten-free nature, it can be used in various value-added products. It originated in Southeast Asia and is cultivated in India, China, Africa, Arabia, and Australia. It was introduced to the United States of America in 1915 from India [7]. Although browntop millet is gluten-free and highly nutritious, it showed less substitution in value-added products such as cookies and pasta due to their coarseness, stickiness, hardness, chalkiness, and presence of bran in grains that make them less palatable. The reduction of some properties or contents such as fiber content, antinutrients, and restriction of water diffusion helps in improving the palatability [8]. Non-thermal techniques like high pressure homogenization, ozone, pulsed electric field, ultrasound, and HPP eliminating hardness, chalkiness, and stickiness in browntop millet better than conventional methods and also helps in reducing the cooking time and help to increase consumption in various ways [9].

Among the listed nonthermal techniques ultrasound-assisted extraction (UAE) is a novel, green, eco-friendly technique, that works on the principle of ultrasonic cavitation or acoustic. It helps break the cell matrix and improve the quality of grains. Ultrasound enhances the texture of grains and, thus, decreases the cooking time; bran water restriction in the grain causes less palatability, ultrasound improves the water diffusion, thus decreasing the cooking time. It loosens the starch matrix, makes the grains structurally weak for faster absorption of water and quicker gelatinization, and produces a softer texture upon cooking. It also decreases the hardness of grains like white rice, buckwheat, brown rice, and basmati rice making them more palatable, and helps to prepare value-added products [10-12].

Another novel technique is high-pressure processing (HPP), which is extensively utilized in lowering the pathogen by enhanced pressure. It is treated to a force of 400 to 600 MPa at ambient or cooled temperature for 1 to 15 minutes. Apart from pathogen elimination, changes in the hardness, coarseness, stickiness, and chalkiness of the grains can be achieved using HPP [7]. HPP-treated grains showed higher digestibility and starch with increased swelling capabilities. It showed high water penetration in grains like white rice, buckwheat, foxtail millet, and brown rice, causing higher gelatinization and making it more palatable [13-16]. A study on the palatability of foxtail millet using HPP was done. It showed the increased consumption of grain intake rate due to an increase in the degree of gelatinization, decrease in diffusion coefficient, and uptake of water of the HPP-treated grains, giving way to scope for the manufacture of more palatable value-added products than the untreated ones [16].

2. Materials and Methods

2.1 Raw materials

Browntop millets were obtained from Shorapur Farmers Company Ltd, which is sponsored by ICAR-IIMR Hyderabad India. All the chemicals and reagents used were analytical grade and bought from Loba Laboratories Pvt. Ltd. and Sigma Aldrich Solutions.

2.2 Browntop millet treatment using ultrasound and high-pressure processing

Browntop millets are processed in both ultrasound (US) (Hielscher's UP200St ultrasonic processor, operating at a frequency of 20 kHz) and high-pressure processing (HPP) equipment's (KK Life Science-KK-HPP-TE) for 5-30 min (5 min interval) at 100, 200 W and 300, 400 MPa with millet to water ratio of 1:5 (w/v). For ultrasound, the experiment was carried out according to [17] and for HPP the experiment was conducted in a polyethylene terephthalate (PET) bottle. The bottles are submerged in a cylindrical tank. Throughout the procedure, the temperature was maintained at 12±2 °C. Following the treatment, the water was filtered, and the grains were dried at 60 °C in a cabinet dryer until their moisture content had returned to 7% as it was before the treatment. Mesh number 212 is used to sieve the treated gains. Until further examination, US & HPP-treated browntop millet flour (US&HPPTBTMF) is kept in airtight standup pouches.

2.3 Functional properties of US & HPPTBTMF

2.3.1 Water holding capacity (WHC)

According to [18] WHC for US&HPPTBTMF was done using the centrifugation method with a little modification. To 1 g of flour, 5 mL of oil was added in the tubes and centrifuged at 1000 x g for 15 mins. The supernatant was discarded and the weight of the sediment was measured and calculated according to equation 1

$$\text{WHC} = \frac{[(\text{Weight of sediment} - \text{weight of empty tube})]}{\text{weight of sample}} \quad (1)$$

2.3.2 Oil holding capacity (OHC)

OHC of the samples was measured similar to WHC using the centrifugation method with a little modification. To 1 g of flour, 5 mL of oil was added in the tubes and centrifuged at 1000 x g for 15 mins. The supernatant was discarded and the weight of the sediment was measured and calculated according to equation 2 [19].

$$\text{OHC} = \frac{[(\text{Weight of sediment} - \text{weight of empty tube})]}{\text{weight of sample}} \quad (2)$$

2.3.3 Solubility & Swelling power (SP)

SP of the US&HPPTBTMF was determined using centrifugation method. According to [20] approximately 1 g of flour was mixed with 10 mL of distilled water in a centrifuge tubes and heated at 85 °C for 30 min in a water bath, and cooled at room temperature, then centrifuge for 15 min at 3000 x g and the supernatant was evaporated in hot air oven at 105 °C for 30 min and weigh the supernatant after drying and weigh the sediment after centrifugation and calculate the SP and solubility using equations 3 & 4 [21].

$$\text{Solubility (\%)} = \frac{\text{Weight of soluble fraction}}{\text{weight of sample}} \text{ X } 100 \quad (3)$$

$$\text{Swelling power (g/g)} = \frac{\text{Weight of sediment}}{\text{weight of sample}} \quad (4)$$

2.4 Anti-nutritional factors

2.4.1 Estimation of tannins

Tannins and phytates were determined using the method described by Gull *et al*. (2016), with minor modifications. To determine the tannin content of US/HPPTBTMF, 1 g of flour was dissolved in 40 mL of 10% methanol filtered, and made up to 50 mL. 1 mL of material was combined with 10 mL of 35% sodium carbonate to make up 100 mL. The absorbance was measured at 750 nm after 50 minutes. The quantity of tannin contained was determined as tannic acid equivalent using the standard curve.

2.4.2 Estimation of phytates

To estimate the phytates content in US/HPPTBTMF, 1 g of sample was dissolved in 10 mL of 0.2 N HCl in an orbital shaker for one hour at room temperature and centrifuged at 3000 x g for 30 min. 3 mL of supernatant was collected and mixed with 1 mL of wade reagent and vortexed for 10s. The absorbance was taken at 500 nm along with a blank solution of 3 mL of extract and 2 mL of 2.4% of HCl. The standard plot was done using sodium salt of phytic acid [22].

2.5 Statistical analysis

All the flour samples were produced in three separate batches; every experiment was run three times and results were presented as the mean±standard deviation (SD). The obtained data were subjected to analysis of variance (ANOVA) to identify the statistical difference (p<0.05) with Minitab statistical software 20.3.0.0, and Origin Lab 2021 was used to create graphs and figures.

3. Results and Discussion

3.1 Water Holding capacity (WHC)

To determine the food hydration potential WHC is essential and helps to understand how the food product or flour will behave upon formulation and how it will impact the end product in terms of appearance, mouthfeel and consistency [18]. From the Table 1, it was observed that US treated grains flour showed higher WHC at 200 W 20 min (1.68 g/g) compared to 100 W samples and control (1.43 g/g). Also, WHC increased with increase in treatment time and power, this may be due to the US formed microjets and higher shearing force to the grains that broke the starch granules and facilitates water penetration and binding inside the pores [23]. Similar results were also observed in brown rice [24]. At 25 min of 200 W (1.59 g/g) treatment, there is a decrease in WHC this might be due to the unwinding of starch granules during treatment that results in decrease the availability of water binding sites due to development of numerous hydrogen bonds with free molecules [25]. Similar results were also observed in foxtail millet [21].

Similar trend were also observed in HPPTBTMF. 400 MPa 20 min treated sample showed higher (1.84 g/g) WHC compared to 300 MPa samples and control (1.43 g/g). This might be due to increase in damaged starch content and breaking of weak connections between amylose and amylopectin molecules by the external forces such as pressures [26]. Similar results were also observed in finger millet [27]. At 25 min of 400 MPa treatment the WHC decreased (1.80 g/g) compared to control which might be related to immobilization properties in the kernel and endosperm that caused structural changes [28] due to external force. According to [15] flour or rice with higher water uptake claim to have more palatable properties. Also, the flour with higher WHC have more hydrophilic constituents like polysaccharides [29].

3.2 Oil holding capacity (OHC)

OHC is an important factor that defines an ingredient's ability to physically contain fat content. Fat improves the mouthfeel and flavor retention of meals [25]. From the Table 2 it was observed that there is increase in OHC as increase in treatment time and power compared to control (1.14 g/g). Sample treated at 200 W for 20 min (1.44 g/g) showed highest OHC compared to all the samples i.e., 100 W & control. This increase in OHC indicates changes in proteins, polar aminoacids and hydrophobic domain of macromolecules by ultrasound [30]. The disruption of starch granules by ultrasonication, which lowers the porosity of the starch particles that were unable to bind the oil effectively, may be the cause of the reduction in OHC seen at 25 to 35 minutes.

Similar trends were also observed in HPPTBTMF; at 400 MPa 20 min treated sample showed higher OHC (1.61 g/g) than 300 MPa samples and control (1.14 g/g). This might be associated with the deformation in the internal structure of the starch granules which may expose more hydrophobic portions of the amylose-lipid complex [27]. During the HPP treatment, the internal structure was changed or disrupted, some of the large particles disintegrated into smaller ones, and the structural porosity and the specific surface area increased. All of these changes exposed the lipophilic groups, which eventually led to the enhancement in OHC [31]. Also, at 25 min (1.52 g/g). There is decrease in OHC of the samples at both pressures 300 & 400 MPa, this could be because of a higher number of uncharged amino acid side chains at lower pH values that are brought to the surface at higher pressures because of the absence of other stabilizing electrostatic interactions within the side chains themselves [32]. According to [33] flour with higher OHC have the benefits in structural interactions in foods to improve the palatability.

3.3 Swelling power (SP)

SP defines the interactions between amorphous, crystallinity, and flour particles WHC. It varies depending on amylose to amylopectin ratio, and molecular weight distribution. It also indicates the intermolecular non covalent bonding of the starch. From Table 1 it was observed that SP was highest in the US treated samples compared to the control (7.51 g/g). Out of all the treated samples, 200 W 20 min (10.24 g/g) displayed the highest SP; this could be associated with disruption of water molecules, and structure of starch granules by ultrasonication. Due to the hydrogen bonds formation the untied-OH group of amylose and amylopectin, increases the capacity to absorb water [25].

Increasing ultrasound treatment time tent to decrease the SP of USTBTMF, which can be observed at 25-30 min of treated samples at both power levels. This might be because of defect on the granules due to prolonged treatment time, broken starch chains and penetration of water for hydration [34] similar results were observed in quinoa flour [35] Also, these results are in align with WHC. Both WHC, SP helps in preventing the loss of moisture content in the sample during processing and have the direct influence on the food sensorial parameters such as mouth feel, freshness, and texture [25].

Similarly, samples treated in HPP at various pressures i.e., 300 & 400 MPa showed same trend like US. HPP broken the hydrogen bonds between the amylose and amylopectin, after breaking the hydroxyl groups are free to form bond with water molecules thus increased the SP in HPP treated samples at 400 MPa 20 min (10.38 g/g) compared to control as shown in Table 2 [26]. Decrease in SP associated to amylose-liquid complex entanglement to amylopectin molecules, which restricts the swelling of starch molecules [36] According to [37] highest swelling power shows increase in palatability and vice versa. Also, [37] mentioned that lowest palatability caused by decrease in SP and higher relative crystallinity (RC), In our previous study [17] highest

RC of the USTBTMF was observed in samples of 25-30 mins in both 100 & 200 W which explains that lower RC helps in improves palatability.

3.4 Solubility

The solubility of the sonicated flour increased with increasing sonicated power and time, and the highest value was observed at 200 W 20 min (14.93%) compared to control (11.76%), which may be attributed to the hydrolysis of starch granules caused by ultrasonic treatment. Increased ultrasonic power and time enhance the exposure of hydrogen bonds because of the degradation of potato flour, which induced an increase in the solubility of starch granules [38]. Elimination of fraction of soluble compounds along with water, resulting in US-treated flours with lower amounts of available soluble compounds at the moment of measurement [39]. Similar results were observed in buckwheat grains [10].

In HPP treated samples similar trend was observed in which, Increase in solubility along with the pressure and time was observed and highest value was found to be at 400 MPa for 20 min (14.84) the reason might be attributed by the leaching of soluble components along with the crude fat (lighter and present in the top layer) from the pressurized HPPTBTMF into the water and form an emulsion [40]. A decrease in solubility was found for samples treated at both pressures i.e., 300 & 400 MPa for 30 and 25 min respectively as shown in Table 2. This decrease in values suggested strengthening of the bonds, with an increase in the interactions among amylose and amylopectin molecules, impeding them from leaching out of the granules [41] Similar results were also observed in waxy rice [42] and rice starch [43].

3.5 Antinutritional factors

3.5.1 Tannins

It has been observed that anti-nutrients (phytates and tannins) in food items can combine with several types of mineral elements to produce complexes that prevent the body from absorbing and using them [22]. Tannins functions as an anti-nutritional factor because of its tendency to precipitate proteins in food and reduces the nutrients bioavailability [23].

US/HPPTBTMF was estimated for the tannin's contents; from the table 2 it was observed that there is decrease in tannin content with increase in both US power and time. The tannin content in raw BTM flour is (110.33 mg) and after the treatments it was ranged from (96.31-18.23 mg/100 g) for US and (94.22-38.98 mg/100g) for HPP. It was observed that there is significant reduction in the content of tannins after the treatment which was associated to the hydrolysis of ester linkages in the tannin during homolysis of the water into ions H^+ and OH^-. Ultrasound helped converting tannic acid into the gallic acid and induces leaching out from the sample [23].

Similar trend was observed in HPP treated sample; it was observed that there is decrease in tannins content with increase in HPP pressure and treatment time (300 & 400 MPa for 5-30 min). This is associated with the high pressure, impacting the cells that eventually expels the tannins to the extracellular medium [44]. According to [45, 46] the presence of tannins leads to lower the palatability and vice versa of the food materials.

3.5.2 Phytates

The phytates serve as antinutrients by chelating the minerals found in millets. The phytate content of the samples may be considerably decreased by increase in US treatment power and time and it ranges from 324.33 to 85.66 mg/100 g compared to control (404.67 mg/100 g) this is due to deterioration of phytates to lower inositol phosphate that reduced the phytate content by sonication process in the USTBTMF [47]. Similar trend was observed in HPPTBTMF and it ranged from 321.66 to 78.93 mg/100 g as shown in Table 2, the reason might be due to the increased solubility of phytic acid-cation complexes [16]. According to [48] presence on antinutritional factors decreases the palatability of the foods.

Table 1: WHC, OHC, SP, solubility of USMBTMF

S. No	Ultrasound (US) power watts	Treatment time (min)	Water holding capacity (g/g)	Oil holding capacity (g/g)	Swelling power (g/g)	Solubility (%)
1.	100 W	Control	1.43 ± 0.21^{i}	1.14 ± 0.15^{i}	7.51 ± 0.32^{i}	11.76 ± 0.32^{k}
2.		5	1.45 ± 0.31^{hi}	1.19 ± 0.51^{ghi}	7.84 ± 0.53^{h}	12.21 ± 0.45^{j}
3.		10	1.48 ± 0.25^{fghi}	1.23 ± 0.11^{fgh}	8.31 ± 0.55^{f}	12.72 ± 0.51^{i}
4.		15	1.55 ± 0.11^{cdef}	1.28 ± 0.22^{cdef}	8.86 ± 0.36^{d}	13.56 ± 0.49^{e}
5.		20	1.64 ± 0.36^{ab}	1.34 ± 0.24^{bc}	9.67 ± 0.43^{a}	14.32 ± 0.56^{b}
6.		25	1.58 ± 0.15^{bcd}	1.23 ± 0.23^{fgh}	9.15 ± 0.11^{a}	13.83 ± 0.20^{cd}
7.		30	1.56 ± 0.21^{bcde}	1.18 ± 0.15^{hi}	8.58 ± 0.39^{e}	13.31 ± 0.75^{f}
8.		35	1.52 ± 0.32^{defgh}	1.06 ± 0.11^{j}	8.07 ± 0.36^{g}	12.93 ± 0.26^{h}
9.	200 W	5	1.47 ± 0.44^{ghi}	1.27 ± 0.22^{def}	8.23 ± 0.25^{f}	12.84 ± 0.43^{hi}
10.		10	1.53 ± 0.32^{defg}	1.31 ± 0.15^{bcde}	8.68 ± 0.20^{e}	13.76 ± 0.55^{c}
11.		15	1.62 ± 0.25^{a}	1.35 ± 0.11^{b}	9.23 ± 0.36^{c}	14.33 ± 0.51^{b}
12.		20	1.68 ± 0.36^{abc}	1.44 ± 0.26^{a}	10.24 ± 0.47^{h}	14.93 ± 0.51^{a}
13.		25	1.59 ± 0.31^{bcd}	1.33 ± 0.11^{bcd}	10.12 ± 0.28^{h}	14.28 ± 0.36^{b}
14.		30	1.51 ± 0.61^{efgh}	1.25 ± 0.22^{efg}	9.72 ± 0.51^{b}	13.95 ± 0.64^{c}
15.		35	1.45 ± 0.20^{ghi}	1.22 ± 0.15^{fgh}	9.14 ± 0.31^{c}	13.15 ± 0.35^{g}

Table 2: WHC, OHC, SP, solubility of HPPMBTMF

S. No	High-pressure processing (MPa)	Treatment time (min)	Water holding capacity (g/g)	Oil holding capacity (g/g)	Swelling power (g/g)	Solubility (%)
1	300 MPa	Control	1.43±0.21^{g}	1.14±0.15^{h}	7.51±0.32^{h}	11.76±0.52^{i}
2		5	1.51±0.30^{fg}	1.25±0.20^{gh}	7.92±0.23^{g}	12.12±0.15^{h}
3		10	1.55±0.20^{ef}	1.29±0.28^{def}	8.67±0.20^{f}	12.68±0.30^{g}
4		15	1.61±0.17^{de}	1.35±0.20^{cde}	8.91±0.36^{e}	12.98±0.55^{f}
5		20	1.65±0.30^{cd}	1.42±0.15^{bcd}	9.25±0.41^{d}	13.40±0.32^{e}
6		25	1.80±0.36^{ab}	1.57±0.17^{abc}	9.85±0.32^{c}	14.08±0.36^{bc}
7		30	1.78±0.26^{ab}	1.51±0. 15^{bc}	9.12±0.11^{d}	13.85±0.45^{d}
8	400 MPa	5	1.57±0.28^{def}	1.23±0.20^{fg}	8.89±0.58^{e}	12.57±0.52^{g}
9		10	1.64±0.51^{cd}	1.33±0.25^{def}	9.21±0.16^{d}	13.16±0.43^{f}
10		15	1.72±0.15^{bc}	1.48±0.12^{bcd}	9.95±0.802^{bc}	13.89±0.80^{cd}
11		20	1.84±0.21^{a}	1.61±0.26^{a}	10.38±0.86^{a}	14.84±0.15^{a}
12		25	1.80±0.12^{a}	1.52±0.26^{ab}	10.11±0.44^{b}	14.17±0.30^{b}

Table 3: Anti-nutritional properties of USMBTMF

S. No	Ultrasound (US) power watts	Treatment time (min)	Phytates (mg/100 g)	Tannins (mg/100 g)
1	100 W	Control	404.67±0.73^{a}	110.33±0.73^{a}
2		5	324.33±0.96^{b}	96.31±0.87^{b}
3		10	257.67±0.55^{c}	72.15±1.11^{d}
4		15	207.33±0.52^{d}	61.07±1.23^{ef}
5		20	195.77±0.81^{d}	54.07±1.03^{fgh}
6		25	155.70±0.23^{e}	47.40±0.92^{h}
7		30	110.33±0.52^{fg}	32.14±0.11^{i}
		35	85.66±0.15^{h}	27.33±1.18^{i}
8	200 W	5	314.33±0.68^{b}	88.23±0.45^{c}
9		10	246.33±0.85^{c}	67.01±0.78^{de}
10		15	192.04±0.40^{d}	58.67±1.01^{fg}
11		20	149.14±0.46^{e}	51.15±1.68^{gh}
12		25	117.33±0.33^{f}	34.33±1.24^{i}
13		30	92.33±0.51^{gh}	28.67±0.91^{i}
14		35	86.37±0.18^{h}	18.23±1.45^{j}

Table 4: Anti-nutritional properties of HPPMBTMF

S. No	High-pressure processing (MPa)	Treatment time (min)	Phytates (mg /100g)	Tannins (mg /100g)
1	300 MPa	Control	404.67±0.73^{a}	110.33±0.73^{a}
2		5	321.66±0.97^{b}	94.22±0.37^{b}
3		10	246.85±0.61^{c}	82.96±0.18^{cd}
4		15	191.18±0.59^{e}	67.40±0.28^{e}
5		20	118.47±0.72^{f}	53.06±0.25^{f}
6		25	97.26±0.57^{g}	42.32±0.85^{gh}
7		30	86.67±0.51^{gh}	33.06±0.59^{i}
8	400 MPa	5	308.67±0.51^{b}	85.63±0.57^{c}
9		10	216.85±0.22^{d}	76.73±0.46^{d}
10		15	176.18±0.37^{e}	63.99±0.15^{e}
11		20	93.43±0.69^{gh}	49.57±0.16^{fg}
12		25	78.93±0.47^{h}	38.98±0.23^{hi}

4. Conclusion

Browntop millet was modified using non thermal technologies such as ultrasound and high-pressure processing and studied its impact on functional and antinutritional properties**.** WHC improved significantly with the increase in US power level, high pressure and time, attributed to the structural disruptions like starch granules breakdown and increased water binding. The optimal WHC was observed at 200 W for 20 min (1.68 g/g) in USTBTMF and 400 MPa for 20 min (1.84 g/g) in HPPTBTMF, with a subsequent decline due to the structural degradation. Similarly, OHC increased with the treatment time and intensity, suggesting enhanced hydrophobic domain exposure. SP followed a comparable trend, peaking at moderate treatment levels due to hydrogen bonding with amylose and amylopectin, while excessive treatments reduced SP. Solubility of the flour increased due to structural changes and hydrolysis during US and HPP treatments, but excessive pressure or time reduced solubility by strengthening the internal bonds. Anti-nutritional factors like tannins, and phytates were significantly reduced, attributed to structural hydrolysis and enhanced solubility of these compounds. Overall, US and HPP enhanced the functional properties of BTM flour, while deteriorating the anti-nutritional components, demonstrating their potential to increase palatability in food formulation.

5. Credit Author Statement

Addanki Mounika: Formal analysis, Data collection, Data Interpretation, Investigation, Research work, Writing-original draft and Editing. Shanmugam Akalya: Conceptualization, designing of experiments, Project administration, Reviewing, Editing, and Supervision. Sinija V.R.: Project administration, Reviewing, Editing, and Supervision.

6. Declaration of Interest

The authors declare no conflict of interest.

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