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Effect of parboiling treatment on de-husking of foxtail millet (*Setaria italica* L.)

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Abstract

De-husking of foxtail millet is considered tedious work due to the small size of the millet. A study was performed to determine the de-husking parameters and also analyzing the quality of foxtail millet. The foxtail millet was soaked for 5h; then the millet was steamed for 10 ± 1 min in a laboratory-scale parboiling unit and then drying at 50°C for 2 hours till the moisture content reaches 12% (w.b). An increase in length, breadth and thickness was observed from 2.66mm, 1.30mm and 1.32mm to 2.68mm, 1.41mm and 1.5mm, respectively. The thousand kernel weight and volume were also found to increase from 2.92g to 3g and 4ml to 5.5ml. The water absorption capacity of the millets was found to increase by three folds. The bulk density and packed density were also found to increase from 0.7462 g/ml to 0.5917g/ml and 0.7575 g/ml to 0.6578 g/ml, respectively. The colour of the millet was improved after the parboiling treatment. The head grain yield of the millet was found to increase from 63% to 77.5%. The brokens yield reduced from 18.5% to 2.5% after the parboiling treatment.

Keywords: Foxtail, parboiling, de-husking, physical, gelatinization

Introduction

Foxtail millet (*Setaria italica* L.) is the oldest crop cultivated in 5900 BC in North-western China. The domestication of the foxtail millet is believed to be originated in the region between Afghanistan and India. It is a crop belonging to the family Poaceae and subfamily Panicoideae (Al-Khayri *et al.*, 2018) ^[1]. Foxtail millet is also known around the globe as Italian millet, Italian foxtail, German millet, Siberian millet and foxtail millet grass. In India, foxtail millet is commonly named Tenai in Tamil, Kakum in Hindi and Navane in Kannada. Foxtail millet is the sixth-highest yielded grain all around the world in terms of production. It is also the second-highest millet produced in the world as it has been grown in and around 26 countries.

Foxtail millet is a highly nutritious grain that is considered as a competitor to the rice and wheat in the world consumption scenario. The millet contains 11-12% protein, 0.45-0.50% ash, 2.38-2.50% fat and 75% carbohydrates (Amadou *et al.*, 2013) ^[2]. The protein concentration present in the millet makes the millet a great protein source. The essential amino acid profile in the millet makes it a great functional food as it is rich in lysine content (Saleh *et al.*, 2013) ^[17]. The presence of a good amount of crude fibre present in the foxtail millet helps in the increase of the bowel movements and thus produces a good laxative effect, which is beneficial for a healthy digestive system (Sharma & Niranjana, 2018) ^[18]. The higher amount of sitosterol among all the grains makes it lowers the serum cholesterol (Dharmaraj *et al.*, 2016) ^[5]. There is a good amount of α -glucans (42.6%), which increases sugar and cholesterol metabolism, resulting in hypoglycaemic and hypocholesterolemic effects. These two helps in the prevention of cardiovascular diseases. The presence of all these nutritional benefits has made foxtail millet a good material for the preparation of normal household meals, nourishing soup, cereal porridges and pancakes (Sharma & Niranjana, 2018) ^[18].

Morphologically the foxtail millet is annual grass having slim, vertical, leafy stems. The millet can grow up to a height of 120-200 cm (Al-Khayri *et al.*, 2018) ^[1]. The generation time from planting to flowering is 5-8 weeks and the time from planting to seed maturity is approximately 8-15 weeks (Doust *et al.*, 2009) ^[6]. The structure of the foxtail millet is similar to the structure of rice. The millet contains husk in the body as a separate part. The grain is occupied by 13.5% (w/w) of husk.

The bran and germ constitute 1.5 -2% (w/w) of the grain and fully cover the grain (Dharmaraj *et al.*, 2016) [5]. The non-edible part of the grain is the husk, and the millet is processed to remove the husk by the de-hulling process. The bran of the de-husked grain is removed by polishing and can be used similar to rice to prepare traditional and modern products (Singh R. Ushakumari *et al.*, 2004) [25].

The de-husking of millets mainly has two steps; loosening of husk and removal of husk. This traditional method involves high manpower, drudgery and this method is highly time-consuming. In the foxtail millet, the husk is tightly attached to the endosperm of the grain. The loosening of husk is done with two methods; dry method and wet method. The dry method removal of husk and bran is traditionally being separated by hand pounding or with the help of a wooden pestle in a wooden or stone mortar. The studies have also found that applying various hydrothermal treatment increases the de-husking efficiency by easy removal of husk. Hydrothermal treatment or parboiling is considered a method of pretreatment before the de-hulling process. Parboiling is found to harden the grains and increases the milling efficiency. The hydrothermal or parboiling will enhance the millets' de-husking, which will tend to increase the cooking characteristics of the grain. The edibility of the grain is higher in the case of de-husked millets. The parboiling process is extensively practiced for rice, wheat, and barley (Dharmaraj & Malleshi, 2011) [4]. The recent studies on parboiling and extraction of oil from bran has been conducted with assistance of novel technologies like ohmic heating, ultrasound-assisted, radio frequency drying, microwave-assisted etc., which have increased the importance of studying the hydrothermal technology for grain foods (Naik *et al.*, 2020, 2021) [11, 12].

Parboiling as pretreatment when given to pigeon pea where also found to reduce the power losses, increase the milling yield and increase the de-husking efficiency (Tiwari *et al.*, 2010) [22]. A study was also reported to have better decortication and improved physical properties as result of improvement in the hardness, when treated finger millet was treated hydrothermally (Usha, 2013) [23]. Based on the preliminary analysis conducted, parboiling could be used as an effective treatment to improve millets' de-husking. In this study the effect of parboiling treatment on de-husking of foxtail millet and its effect on milling and quality parameters is conducted.

Materials and Methods

Procurement of Sample

The foxtail millet was purchased from the market of Thanjavur district in Tamil Nadu. It was then cleaned by removing the unwanted particles, and it was stored in a sealed container by maintaining a moisture content of 12% (w.b). The commercially available samples have moisture content in the range of 11-12% (w.b).

Parboiling treatment

Soaking

The soaking time and temperature were optimized from the preliminary studies that had been conducted for different time intervals ranging from 2 to 8 h. Guided from the preliminary studies, the foxtail millet has been steeped in excess water for 5 hours at room temperature and was used for the next step of parboiling, steaming.

Steaming

The soaked samples were steamed in the laboratory scale parboiling unit developed by IIFPT. The repeated trials

optimized the steaming time for a different steaming time ranging from 1 minute to 30 minutes. The optimum duration of steaming has been found out by checking the gelatinization of starch in the millets. This was done by taking the millets out of the steaming condition at each time duration and checking for the complete gelatinization. The gelatinization was complete when there was an absence of white coloured belly, which was found when the millet was cut open and placed in between two glass slides. The glass slides were pressed and if there is a translucent layer has been formed, it is said to be perfectly steamed. The optimized steaming time was found to be 10 ± 1 min and the soaked millets were steamed for this optimized time duration of 10 ± 1 min in the atmospheric pressure.

Drying

The steamed foxtail millet was taken from the laboratory scale parboiling unit. The millets were uniformly spread in steel plates with uniform thickness and was dried in hot air oven at atmospheric pressure. The hot air oven temperature was maintained at 50°C and dried for 2 hours as it reached the storage temperature of $12 \pm 2^{\circ}\text{C}$. This millet after all the three steps were considered as parboiled millet and was packed in sealed pouches for using in the de-husking trials

Physical properties

The physical properties of the procured foxtail millet were studied. The major physical properties studied were: Length, width, thickness, thousand kernel weight, thousand kernel volume, bulk density, tapped density, colour, water absorption capacity and cooking time.

Length, Width and Thickness

A sample of 50 grains were sorted out randomly. The length, width and thickness of the grains are measured with vernier calipers with a least count of 0.01mm and the corresponding mean values were determined (Sunil *et al.* 2016) [19].

Thousand kernel weight and thousand kernel volume

A thousand grains were counted manually by splitting it into 10 batches, each containing a hundred grains. The batches were combined, then the weight of the thousand kernels was weighed on a digital electronic balance. The thousand grains' volume was measured by conveying a thousand kernels into a 10ml measuring cylinder, and the volume was found out (Varnamkhasti *et al.*, 2008) [26].

Bulk density

The bulk density of the samples were calculated by filling a measuring cylinder of 100ml with the samples. The weight of the filled container were measured in a digital weighing balance. Bulk density was calculated as the ratio of the foxtail millet samples' weight to the volume of the container (Sunil and Natarajan, 2017) [20].

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample packed(g)}}{\text{Known volume (ml)}}$$

Packed density

The samples' packed density was obtained by filling a measuring cylinder of 100ml with samples and giving an additional tapping of 50 times to the cylinder on a flat surface. The weight of the cylinder were measured after the tapping is finished. The tapped density is calculated as the ratio of the

weight of the samples(g) to the volume of the measuring cylinder(ml) (Falade *et al.*, 2014)^[7].

Water absorption capacity

Water absorption of the samples was determined by taking 5g of the sample and this was mixed to 15 mL of distilled water in a test tube. The air bubbles were removed by stirring using a wire. The mixture of millet and water was allowed to stand for 12 hours. The water was strained using a wire filter and the surface of the millet was adhered to using blotting paper. The water absorption index was measured by the difference in the samples' weight (Nikitha & Natarajan, 2020)^[13].

$$\text{Water absorption capacity(\%)} = \frac{\text{Increase in weight}}{\text{Initial weight}} \times 100 \quad \dots(1)$$

Colour analysis

The colour of the grain samples were analyzed by Hunter colour lab colorimeter. Black and white standardizing templates were used for the initial calibration of the colorimeter. After that, standardization samples were placed over the colorimeter's eye to measure the CIELAB L*, a* and b* values. The same procedure was repeated thrice and the average of the three were determined. The control sample's color difference with pre-treated millet samples was found out using the equation below in terms of ΔE^* (Sunil and Neeraja 2018)^[21].

$$\Delta E^* = [(L_0^* - L^*)^2 + (a_0^* - a^*)^2 + (b_0^* - b^*)^2]^{1/2}$$

Where L_0^* , a_0^* , b_0^* are the colour parameters of the untreated control sample.

Cooking time

The sample's cooking time was determined by cooking the sample in a water bath to maintain the boiling water's uniform temperature. For the measurement of cooking time, 50 ml of water was taken in 100 ml beakers and 5g of the native and pre-treated millets were added into a beaker. Boiling of the millets was started and at every 20 seconds, the samples pressed against two glass slides. While pressing there was no lateral movement of the two glass slides. The completion of the cooking time was complete when the kernels no longer had opaque or uncooked centers. The time required for the complete disappearance was considered as the optimum cooking time (Joyner & Yadav, 2015)^[8]. The slides used were cleaned each time after their use

De-husking of millets

Abrasive grain polisher

The abrasive grain polisher was used for de-husking of the millets. The machine contained cast iron cylinder (wheel) coated with emery, surrounded by a perforated metallic sieve casing. A ½ hp electric motor provided the drive for the emery wheel.

In this, the millet grain-fed from the hopper is forced between the emery stone and the perforated steel plate that encloses the emery stone. Friction between the grains and steel parts of the polisher causes husk to be scrapped off. In this process, the husk removed from the grain, is pushed through the perforated screen. The de-husked grain and the hull are

collected in separate outlets.

Head grain yield (in %)

Head grain yield is the amount of head grains obtained from the total weight that has been feed into the grain polisher, which includes the head grain weight, husk weight and broken weight (Rathore & Singh, 2017)^[16].

$$\text{Head grain yield} = \frac{\text{weight of head grain(gm)}}{(\text{head grain weight} + \text{husk weight} + \text{broken weight})} \times 100 \quad \dots(2)$$

Brokens yield (in%)

The yield of brokens obtained is the weight of broken grains obtained from the total weight fed to the grain polisher (Rathore & Singh, 2017)^[16].

$$\text{Brokens yield} = \frac{\text{weight of broken grains}}{(\text{head grain weight} + \text{husk weight} + \text{broken weight})} \times 100 \quad \dots(3)$$

Husk yield (%)

The amount of husk or seed coat that had been received after the total de-husking of the millets fed into the grain polisher is said as the husk yield (Rathore & Singh, 2017)^[16].

$$\text{Husk yield} = \frac{\text{weight of husk}}{(\text{head grain weight} + \text{husk weight} + \text{broken weight})} \times 100 \quad \dots(4)$$

Results and Discussion

Physical properties

The grain dimensions of the millet increased slightly after the parboiling treatment. The length, width and thickness increased from 2.66mm, 1.30mm and 1.32mm to 2.68mm, 1.41mm and 1.5mm, respectively. Parboiling caused the swelling of the millet grains, leading to the gelatinization of starch and increasing the foxtail millet dimensions. The thousand kernel weight and thousand kernel volume also tend to increase slightly. The raw millet tends to increase from 2.92g to 3g after the parboiling treatment. Similarly, the thousand kernel volume also increases from 4ml to 5.5ml. The increase in the millet grains' weight and volume is due to basic principle of gelatinisation, as the intramolecular hydrogen bonds are broken and the grains absorb water, which leads to swelling of the millets and hence an increase in the weight and volume of the millets.

The bulk density of the raw and parboiled millet had a decreasing trend. The bulk density decreased from 0.7462 g/ml to 0.5917g/ml. The packed density of the raw and parboiled also have decreasing trend 0.7575 g/ml to 0.6578 g/ml. The packed density is considered as the maximum density of the material that would be obtained on compaction. The decrease in the bulk and packed density is due to the increase in the millet dimensions due to starch's partial gelatinization.

The water absorption capacity increased for foxtail millets after parboiling. The raw millet had a water absorption capacity increase by 3 folds, as it increased from 27.75% to 74.7%. The major enhancement is due to the increased presence of starch in the foxtail millets, making the foxtail millet with more hydrophilic nature (Lawal & Adebawale, 2004)^[9]. The increase in the viscosity resulting from the increase of water absorption capacity makes it useful as a thickening agent for the preparation of certain foods.

Table 1: Physical properties of raw and parboiled foxtail millet

Parameters	Raw foxtail millet	Parboiled foxtail millet
Length(mm)	2.66	2.68
Breadth(mm)	1.30	1.41
Thickness(mm)	1.32	1.5
Thousand kernel weight (g)	2.92	3
Thousand kernel volume(ml)	4.0	5.5
Bulked density(g/ml)	0.7462	0.5917
Packed density(g/ml)	0.7575	0.6578
Water absorption capacity (%)	25.75	74.70
Cooking time	13min 12s	15min 15s

Cooking time

Parboiling of foxtail millet showed a significant increase in the cooking time as compared to raw millets. The minimum cooking time for raw millet was 13min 12s while parboiling increased the cooking time to 15m 15s. During the boiling process in parboiling, starch is gelatinized, leaching amylose, and disintegration of protein occurs and leads to filling up empty spaces inside the endosperm. Subsequent cooling leads to the retrogradation process, which results in a tightly packed structure and hardening of the kernel because of amylose molecules' reformation. This strong cohesion between the endosperm cells makes the tightly packed starch to hydrate at a slower rate, resulting in a decrease in absorption rate and an increase in cooking time (Bora *et al.*, 2019; Meresa *et al.*, 2020) [3, 10].

Colour analysis

The millet's color parameters are very important to analyze the change in the grain's physical appearance and, subsequently, consumer acceptability. The L* value indicates the whiteness value of the grain and flour. The L* value of grain has decreased considerably after the parboiling treatment and decortication due to possible leaching of bran pigments into the kernel part during hydrothermal treatment. Similarly, in the case of flours, control and de-husked samples did not show any colour difference, while parboiling treatment caused a decrease in whiteness due to bran pigments in the flour (Palanimuthu *et al.*, 2011; S R Ushakumari, 2009) [24]. The a* and b* values were positive for all the samples, indicating redness and yellowness, respectively. There was not much change in a* of parboiled treatment, but considerable reduction occurred due to de-husking as the husk part in removed revealing the lighter coloured kernel. The a* value of control and de-husked flour has not shown any significant difference. However, the redness value of flour has increased due to enhancement and leaching of pigment during hydrothermal treatment. However, the yellowness index b* has not shown any considerable change due to the treatment. This might be due to the husk's light coloration in foxtail millet (Obadina *et al.*, 2016) [14].

De-husking characteristics

The de-husking characteristics of the foxtail millet had an increasing trend after the parboiling. The head grain yield increased from 63% to 77.5%, which is considered a drastic change. The change occurred as a result of increase of the hardness of the endosperm. The hardening of the endosperm resulted to an easy loosening of husk without the breakage of the millets. The husk yield also increased 18.3% to 20.25%. The broken yield had a considerable decrease due to the hardening of the endosperm. The broken yield value decrease from 18.7% to 2.5%. Rathore and Singh (2017) [16] also had study on the decortication of pearl millet, which was found

have similar results. The study revealed an increase in the head grain yield with a decrease in the amount of broken.

Conclusion

The parboiling process is a pretreatment process, showing positive milling efficiency and increases the edibility of the grain. Head grain yield increased after milling. Colour characteristics have considerably improved along with de-husking characteristics. Water absorption characteristics and cooking time increased for the parboiled millet sample.

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