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Effect of germination and roasting on dimensional, gravimetric and physicochemical properties of white finger millet, KMR-340

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Abstract

In the present investigation, the effect of roasting (120°C, 5 min) and germination (30±3°C, 48 h) on dimensional, gravimetric and physicochemical properties of White finger millet (WFM) KMR-340 were studied and compared with native (untreated) grains. The mean values of all samples' length, width, and thickness ranged from 1.60 to 1.75, 1.45 to 1.60, 1.25 to 1.40mm, respectively. Roasting resulted in a significant ($p<0.05$) increase in length, width, geometrical and arithmetic mean diameter, surface area and volume, whereas significantly ($p<0.05$) reduced thousand grains weight, true density, water activity and the color values of the WFM grains. The germination pretreatment decreased the thousand grains weight, bulk density and true density. A correlation study suggests that the dimensional properties had a significant ($p<0.05$) effect on surface properties like surface area and sphericity. Further it revealed that the bulk density, true density and porosity are completely interdependent (correlation ratio (r) value >0.99). In addition, the weight of thousand grains has a positive relationship (r) value >0.90 with the bulk density, true density and porosity of WFM. The results produced during the study will help the food processors and researchers find the application of roasted and germinated WFM in developing value-added food products.

Keywords: white finger millet, roasting, germination, dimensional properties, physicochemical properties

Introduction

Millet stands in the sixth position among the highest yielding grains in the world. In 2018, the global millet production was estimated to be around 31.02 million tonnes (MT). In case of global millet production, India recorded the highest production of millets (11.64 MT), followed by Niger (3.85 MT) and Sudan (3.75 MT) (FAOSTAT, 2020). Millets are gluten-free, highly nutritious, non-acidic forming, have a low glycemic index, and good dietary properties (Saini *et al*., 2021) [14]. Finger millet (FM) (*Eleusine coracana*) belongs to the family "Poaceae" and is a small-seeded, globose shaped minor cereal with a yellow, white, red, brown, or violet color seed coat. It is native to Asia and Africa and is used as a staple food (Chandra *et al*., 2016; Hassan *et al*., 2021) [3, 5]. FM is resilient, can survive with minimal water, poor soils, increasing temperatures and requires minimal fertilizers and pesticides for growth, offering a viable choice for the marginal farmers. Also, its cultivation imparts less stress on the environment, consequently reducing the agriculture carbon footprint (Gupta *et al*., 2017) [4]. The White finger millet (WFM) KMR-340 is a good source of protein (11.98 g per 100 g), calcium (392 mg per 100 g) and iron (4.72 mg per 100 g) (Ravishankar *et al*., 2019) [13].

Food processing techniques such as decortication, milling, soaking, germination, and roasting enhance nutritional bioavailability and organoleptic properties, decrease anti-nutritional factors, extend shelf life, and add specific flavor and enhance texture well as taste (Yousaf *et al*., 2021) [20]. Roasting is a traditional processing operation that utilizes dry heat treatment (either open pan heating, oven or other techniques) that enhances the digestibility and edibility, improves iron availability and sensory characteristics, decreases anti-nutrition factors in cereals and pulses (Obadina *et al*., 2016; Sharanagat *et al*., 2019; Yousaf *et al*., 2021) [11, 16, 20]. Germination is a natural process of sprouting seedlings, during which starch breaks down into maltose and dextrin due to the action of amylase enzyme. It improves the bioavailability, nutritive value, physic-functional properties and reduces levels of anti-nutrients of cereals and millets. (Adebiyi *et al*., 2017; Najdi Hejazi & Orsat, 2017; Yousaf *et al*., 2021) [1, 10, 20]. The dimensional properties like length, width, thickness, geometric mean diameter, and arithmetic mean diameter play a vital role in designing the sieves to separate unwanted materials from grains. Knowledge of the gravimetric properties like bulk density, true density, and porosity helps determine the drying rate and to help design the packaging requirements in food processing industries, and determine the flow properties. Further, physicochemical properties namely color values and water activity provides information about the degree of perception and availability of free water in a sample, respectively (Ashwani Kumar, Amarjeet Kaur, 2020; Sharanagat *et al*., 2019; Sravani *et al*., 2020) [2, 16, 18]. Despite being nutritious and extraordinary appearance, the effects of roasting and germination on the dimensional, gravimetric and physicochemical properties of WFM, KMR 340 is still unexplored. Thus the present investigation is carried out to determine the effect of thermal treatment (roasting) and germination of WFM, KMR-340 on the dimensional, gravimetric and physicochemical properties. The results produced during the study will help the food processors and researchers to find the application roasted and germinated WFM KMR340 in the development of value-added food products.

Materials and methods

Raw material procurement

The WFM variety KMR 340 was procured directly from College of Agriculture, V.C Farm, Mandya, Karnataka with an initial moisture content of 11.67 ± 0.078 % (wb) for evaluating the engineering and physiological properties. The grains initial moisture content was determined by hot air oven method, at 105°C for 24 hours (AOAC, 1995). The WFM grains were de-hulled using a laboratory abrasive (emery roll) polisher (Model: TM 05, Satake Corporation, Japan), obtaining 96.55% hulling efficiency. These de-hulled grains (N_g) were used for analysis as raw or untreated grain.

Sample preparation

a. **Roasting:** WFM grains were roasted using a pan roasting method (120°C, 5 min), as Obadina *et al* (2016) described to obtain roasted WFM grains (R_g).
b. **Germination:** Germinated WFM grains were prepared by soaking them for 24 hours in distilled water, followed by germination inside the incubator (MAC, Model MWS-231, New Delhi) for 48 hours at 30°C (Najdi Hejazi & Orsat, 2017) [10]. Further, the germinated grains were dried for 12 h at 40°C in a hot air oven (Everflow Scientific Instruments, Chennai).The vegetative part is removed and the sound grains to obtain germinated WFM grains (G_g).

The dimensional properties studied were size (length, width and thickness), geometric mean diameter, arithmetic mean diameter, sphericity, gravimetric properties such as true density, bulk density, porosity and weight of 1000 grains and physiological properties namely color and water activity.

Dimensional Properties

Twenty WFM seeds were selected randomly from a lot and the size of grains were determined by measuring their length (mm), width (mm) and thickness (mm) using digital vernier caliper (Model: mLabs-FC31) having a least count of 0.01mm. The Geometric mean diameter (GMD), Arithmetic mean diameter (GMD), Sphericity, Surface area, Sample volume and Aspect ratio were determined by using formula given by Ashwani Kumar, Amarjeet Kaur. (2020) [2], Sharanagat *et al*. (2019) [16] and Sunil *et al*. (2016) [19].

$$\text{Geometric mean diameter (GMD)} = (L * B * T)^{1/3} \quad (1)$$

$$\text{Sphericity } (\Phi) = \frac{GMD}{L} \quad (2)$$

$$\text{Sphericity } (\Phi) = \frac{GMD}{L} \quad (3)$$

$$\text{Surface area} = \frac{\pi B L^2}{(2L-B)} \quad (4)$$

$$\text{Sample volume} = \frac{\pi B^2 L^2}{6(2L-B)} \quad (5)$$

$$\text{Aspect ratio} = \frac{W}{L} * 100 \quad (6)$$

Where, L= longest intercept (Length), W= longest intercept normal to L (Width) and T= longest intercept normal to L and B (Thickness) and $B = (WT)^{1/2}$

Gravimetric properties

True Density (T.D)

50ml of toluene was taken in a measuring jar. A known weight of grain sample was poured to the measuring jar and rise in the toluene level was recorded. The true density of the grain was calculated by using the following formula.

$$\text{True density} = \frac{\text{Weight of grains (kg)}}{\text{Volume of grains excluding void space (m}^3\text{)}} \quad (7)$$

Bulk density (B.D)

Bulk density was determined by using a container of known volume. The sample was taken into the container for the known volume and weighed. The bulk density was determined using the formula

$$\text{Bulk density} = \frac{\text{Weight of grains (kg)}}{\text{Volume of grains including void space (m}^3\text{)}} \quad (8)$$

Porosity

Porosity of WFM grains was calculated from the bulk Density and true density values (that were found earlier) by using the following formula,

$$\text{Porosity} = \left(1 - \frac{\text{Bulk density}}{\text{True density}}\right)100 \quad (9)$$

Weight of 1000 grains

Thousand WFM grains were randomly selected and weighed using an electronic balance with an accuracy of 0.1g. Test was performed three times and the mean weight of thousand grains was calculated.

Physicochemical properties

Color measurements

The sample's color values were determined using Hunter Lab Colorimeter (Colourflex EZ model: 4510, Hunter Associates Laboratory, Reston, VA). The L*, a*, b* values (L*-lightness to darkness, a*- redness to greenness, b*-yellowness to blueness) of were noted. The color differences (ΔE) between the different WFM grain samples were calculated using a formula defined by Khushbu & Sunil (2020), while Chroma (ΔC), hue angles and whiteness index were determined using an equation defined by Medhe *et al*. (2019)

$$\Delta E = \sqrt{(L - L^*)^2 + (a - a^*)^2 + (b - b^*)^2} \quad (10)$$

$$\Delta C = \sqrt{(a - a^*)^2 + (b - b^*)^2} \quad (11)$$

$$\text{Hue angle} = \tan^{-1}\left(\frac{b}{a}\right) \quad (12)$$

$$\text{Whiteness Index} = \sqrt{(100 - L^*)^2 + (a^*)^2 + (b^*)^2} \quad (13)$$

Where L, a, b and L*, a*, b* are the color parameters of the raw and processed WFM, respectively.

Water activity

The water activity WFM grains were determined using Aqua Lab dew point water activity meter 4TE (METER group Inc., USA).

Statistical analysis

The results obtained from different experiments were analyzed using Minitab statistical software (Version 17). Means were also calculated. The data were subjected to for one way analysis of variance (ANOVA)) with Tukey's test to determine the significant difference between the mean at the 5% level. Differences were measured as statistically significant at p <0.05. Pearson correlation coefficient (r) was used to determine the correlation between the different parameters of dimensional and gravimetric properties.

Results and discussion

Dimensional properties

The values of dimensional parameters such as length, width, thickness, GMD, AMD, and sphericity play a vital role in designing the sieves to separate unwanted materials from grains. The mean values of all samples' length, width, and thickness ranged from 1.60 to 1.75, 1.45 to 1.60, 1.25 to 1.40mm respectively. The results were in agreement with the findings of Ashwani Kumar, Amarjeet Kaur. (2020) [2] and Ramashia *et al*. (2017) [12]. The length and width significantly ($p<0.05$) increased in G_g and R_g (Table 1). Similar observations were obtained by Ashwani Kumar, Amarjeet Kaur. (2020) [2] for germinated FM grains and Sravani *et al*. (2020) [18] for roasted brown-top millet grains. The increase in length and width of the G_g may be because of the irreversible swelling of starch granules and/or attachment of epicotyl and hypocotyl to the grain upon drying. At the same time, the increase in the length and width R_g could be attributed to the expansion of the all dimensions of starchy endosperm that occurred because of rapid removal of moisture during roasting process Sharanagat *et al*, (2019) [16]. However the thickness remained unaltered upon roasting and germination treatments. The AMD and GMD of G_g and R_g values were significantly higher ($p<0.05$) than N_g. This could be due to an increase in the length and width of the grains, which might have occurred due to the roasting and germination process. The former reason is supported by the correlation statistical analysis (Figure 1) which revealed that the AMD and GMD has direct significant ($p<0.05$) relationship with the length, width, volume, surface area and sphericity (correlation coefficient value - $r > 0.85$).

Table 1: ANOVA results of dimensional properties of raw, roasted and germinated White Finger Millet grains

Dimensional properties	N_g	G_g	R_g	R^2 %	P value
Length (mm)	1.60±0.02^c	1.75±0.03^a	1.67±0.02^b	90.47	0.001
Width (mm)	1.45±0.02^c	1.60±0.02^a	1.53±0.01^b	93.33	0.000
Thickness (mm)	1.25±0.01^a	1.40±0.09^a	1.33±0.03^a	46.03	0.157
GMD (mm)	0.97±0.01^b	1.25±0.02^a	1.24± 0.03^a	97.95	0.000
AMD (mm)	1.43±0.00^b	1.56±0.01^a	1.56±0.01^a	98.67	0.000
Surface volume (mm^3)	0.48± 0.01^b	0.83± 0.04^a	0.75± 0.07^a	93.27	0.000
Surface area (mm^2)	3.19±0.04^c	4.46± 0.14^a	4.23±0.22^b	95.10	0.000
Sphericity	75.13±1.78^a	60.57±0.91^b	71.28±3.00^a	92.92	0.000
Aspect ratio (%)	93.16±0.60^a	90.52±1.05^b	84.70±0.06^c	97.43	0.000

All the values are mean ± SD of three replications. Values with different superscripts differ significantly ($p < 0.05$). N_g-Raw grain, G_g-Germinated grain, R_g- Roasted grain The average values of surface volume, surface area, sphericity and aspect ratio of N_g, G_g and R_g are 0.48, 0.83 and 0.75 mm^3; 3.19, 4.46 and 4.23 mm^2; 75.13, 60.57 and 71.28; 93.16, 90.52 and 84.70% respectively. Our findings were closer to that of studies conducted by Ashwani Kumar, Amarjeet Kaur.(2020) and Ramashia *et al*. (2017) [12] in germinated and raw creamy FM grains respectively. The significant ($p<0.05$) increase in the surface volume, surface area in G_g could be due to increase in the size (length and width) because of swelling of starch granules during soaking process of germination, whereas the decrease in the sphericity and aspect ratio in G_g could be attributed to the increment in the length than width and thickness Ashwani Kumar, Amarjeet Kaur. (2020) [2]. Similarly, in R_g, due to increase in the dimensional properties, the surface volume, surface area might have increased sphericity and aspect ratio might have changed and same have been observed in correlation studies.

Gravimetric properties

Processing affected the gravimetric properties of WFM grains and exhibited significant ($p<0.05$) variations (Table 2). BD indicates the degree of the heaviness of the grains and is influenced by the size of particles and the density of the grain. The B.D measurements help design the packaging requirements in food processing industries and determine flow properties (material handling) and wet processing. The ANOVA results of gravimetric properties of N_g, R_g and G_g are represented in Table 2. The mean value of B.D of Ng (750±0.04) was higher than R_g (670±0.01) and G_g (550±0.02). Similar trend was observed by Ashwani Kumar, Amarjeet Kaur. (2020) [2] and Sharanagat *et al*. (2019) in germinated FM and microwave roasted sorghum. The decrease in the B.D of R_g could be due to the disintegration of the starch-starch-protein matrix upon heating or due to the generation of the space between starchy endosperm. However, reduction of B.D in G_g could be attributed to enzymatic activity that breaks complex molecules into simple molecules during germination Sharanagat *et al*. (2019) [16] and Singh *et al*. (2017) [17]. The T.D of N_g (1270 ±0.02) was higher than R_g (1280±0.04) and G_g (1250±0.02). Similar trend was observed by Ashwani Kumar, Amarjeet Kaur. (2020) [2] and Sharanagat *et al*. (2019) [16] in germinated FM and microwave roasted sorghum.

The porosity of N_g (40.98±0.7) was higher than R_g (47.20±0.92) and G_g (55.59±2.28). In G_g because of the shrinking of grains and/or formation of cracks on the skin the porosity might have increased Ashwani Kumar, Amarjeet Kaur. (2020), whereas increase porosity in R_g could be attributed to uneven expansion of grain due to thermal treatment Sharanagat *et al*. (2019) [16]. The weight of thousand grains of N_g (2.3±0.00) was greater than G_g (2.10±0.00) and R_g (2.29±0.01). The decrease in the weight of G_g may be due to the malting loss that occurred during soaking Ashwani Kumar, Amarjeet Kaur. (2020) [2]. Whereas slight decrease in R_g could be attributed to the occurrence moisture loss during roasting process Sharanagat, Jogihalli, *et al*. (2018) [15]. The porosity of was G_g (55.59±2.28%) higher than R_g (47.20±0.92%) and N_g (40.98±0.76 %). Similar trend was observed by Ashwani Kumar, Amarjeet Kaur. (2020) [2] and Sharanagat *et al*. (2019) [16] in germinated FM and microwave roasted sorghum. The thousand grains weight of G_g was reduced than N_g. This may be due to malting loss that occurred during soaking process of germination (Ashwani Kumar, Amarjeet Kaur, 2020) Correlation analysis revealed that the Bulk density, True density and porosity are completely interdependent (correlation ratio (r) value >0.99) (Figure 1). Also the weight of thousand grains has positive relationship (r) value >0.90 with the bulk density, true density and porosity of different processed WFM grains.

Table 2: ANOVA results of gravimetric properties of raw, roasted and germinated white finger millet grains

Gravimetric properties	**N_g**	**G_g**	**R_g**	**R^2 %**	**P value**
Bulk density (Kg/m^3)	750±0.03^a	550±0.02^c	670± 0.01^b	95.24	0.000
True density (Kg/m^3)	1270 ±0.02^a	1250±0.02^a	1280±0.04^a	24.87	0.424
Porosity (%)	40.98±0.76^c	55.59 ±2.28^a	47.20±0.92^b	96.04	0.000
Thousand grains weight (g)	2.3±0.00^a	2.10±0.00^c	2.29±0.01^a	99.83	0.000

All the values are mean ± SD of three replications. Values with different superscripts differ significantly ($p < 0.05$),
N_g-Raw grain, G_g-Germinated grain, R_g- Roasted grain

Physicochemical properties

Color is an important quality parameter and plays a vital role in the overall perception and acceptability of the food product and increases consumers' choice and preferences (Liu *et al*., 2020). Color parameters varied significantly ($p<0.05$) with the different pretreatments. The L*, a*, b*, color differences (ΔE), Chroma (ΔC), hue angles and whiteness index between the different WFM grain samples were represented in (Table 3). The L* value decreased in both G_g and R_g. The L* value of G_g decreased from 63.72±0.41 to 60.61±0.44, whereas it decrease from 63.72±0.41 to 62.58±1.37 in R_g. The redness and greenness index (a*) of R_g (6.80±0.13) was higher than N_g (6.49±0.01) and G_g (6.5±0.03). Further, the R_g (28.49±0.30) had the highest yellowness values (b*), followed by N_g (27.97±0.14) and G_g (28.13±0.10). Similar trend was observed in the studies of Liu *et al*. (2020) for raw white rice and germinated white rice. Also the findings of R_g followed similar trend as that of Sharanagat *et al*. (2019) for microwave roasted sorghum grain. The decrease in lightness (L*), while the increase in redness (a*) and yellowness (b*) in R_g could be due to the effect of roasting, which initiates non-enzymatic browning reaction and subsequently leads to the formation of dark pigments (Kumar Y, Sharanagat VS, Singh L, 2019; Sharanagat *et al*., 2019) [7, 16].

Table 3: ANOVA results of physicochemical properties of raw, roasted and germinated white finger millet grains

Physicochemical properties	**N_g**	**G_g**	**R_g**	**R^2 %**	**P value**
Color values					
L*	63.72±0.41^a	60.61±0.44^b	62.58±1.37^{ab}	76.71	0.013
a*	6.49± 0.01^b	6.5±0.03^b	6.80± 0.13^a	82.45	0.005
b*	27.97±0.14^b	28.13±0.10^b	28.49±0.30^a	63.13	0.050
ΔE	-	3.23±0.43^a	0.98±0.08^b	96.23	0.000
Chroma	29.25±0.06^a	28.88±0.06^b	29.25±0.01^a	95.95	0.008
Hue angle	76.94±0.05^{ab}	77.09±0.19^a	76.58±0.21^b	71.92	0.022
Whiteness Index	45.99±0.52^b	49.74±0.17^a	46.70±0.51^b	95.44	0.000
Water activity	0.69±0.01^a	0.50± 0.01^b	0.43± 0.01^c	99.84	0.000

All the values are mean ± SD of three replications. Values with different superscripts differ significantly ($p < 0.05$).
N_g-Raw grain, G_g-Germinated grain, R_g- Roasted grain

The hue angles of all samples were lower than 90°. The G_g (77.09±0.19) had the highest hue angle followed by N_g (76.94±0.05) and R_g (76.58±0.21). According to Ramashia *et al*. (2017) [12], the hue angle is measured from 0º to 360º in which 0°, 90°, 180° and 270º corresponds to red, yellow, green and blue colors, respectively. Therefore, native and pretreated WFM grains are red to yellowish. In addition, a* and b*values indicate the varying concentration of red and yellow pigmentation in their grains. Whitening Index of $N_{g,}$ G_g and R_g are 45.99±0.52, 49.74±0.17 and 46.70±0.51 respectively and its value increased in G_g than N_g and R_g (Table 3). The Chroma value decreased in G_g than N_g and R_g (Table 3).Similar observations were obtained by Ramashia *et al*. (2017) for milky cream variety FM cultivar. The color difference was higher in G_g than R_g (Table 3) because of increase color values of G_g than N_g. The average values of water activity of N_g (0.69±0.01) was significantly ($p<0.05$) higher Table 3) than G_g (0.50±0.01) and R_g (0.43±0.01).The decrease in the water activity in R_g may be due to removal of water from grains during heating process of roasting pretreatment whereas in case of G_g due to the occurrence of evaporation during drying process of germination the water activity might have reduced.

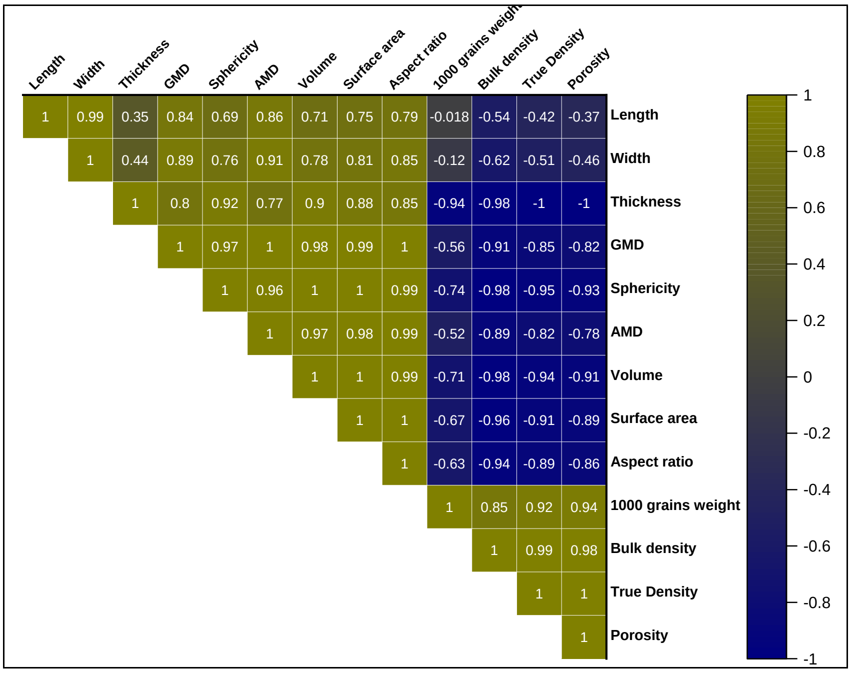

Fig 1: Correlation of effect of processing (Roasting and Germination) on dimensional and gravimetric properties of White finger millet grains

Conclusion

The present investigation revealed that roasting and germination pretreatments had an evident influence on WFM grains' dimensional, gravimetric, and physicochemical properties. Roasting increased length, width, geometrical and arithmetic mean diameter, surface area, and volume. Quicker removal of water content led to a significant reduction in thousand grains weight and water activity. Porous structure formed in roasted grain resulted in low bulk and true density, and higher porosity. The color of the grains reduced upon roasting treatment. Due to the germination pretreatment, the thousand grains weight, bulk density and true density were decreased. Correlation study suggests that gravimetric and dimensional properties had a significant effect on surface properties like surface area and sphericity. The results produced during the study will help the food processors and researchers to find the application roasted and germinated WFM, KMR 340 development of value added food products.

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