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Influence of hydrothermal treatment on proximate composition of milled finger millet (*Eleusine coracana)*

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Abstract
The present study carried out with the aim of milling the finger millet (removing seed coat) and estimating the changes in proximate composition of finger millet. In order to mill the finger millet, initially it was subjected to hydrothermal treatment i.e. soaking at temperature of 30 °C for 24 hours and 70 °C for 1 hour 45 minutes, steaming pressures at 1, 1.5 and 2 kg/cm^2 and drying at 40 °C to obtain the final moisture contents of 12.15% and 14.09% (w.b.). Milling (decortication) of hydrothermally treated finger millet was done with rice polisher with two passes of each 20 s residence time. Different conditions of hydrothermal treatments enable milling to a definite degree for each sample. Influence of hydrothermal treatment was analysed for changes in proximate composition. It was concluded that milled finger millet recorded lower values of protein, fat, ash, calcium and crude fiber as 5.66%, 0.76%, 0.97%, 187 mg/100 g, 1.00% respectively compared to the raw finger millet because of the seed coat removal.

Keywords: Influence, hydrothermal, treatment, milled finger, (*Eleusine coracana*)

1. Introduction
The grain finger millet (*Eleusine coracana* L.) belonging to the family *Poaceae.* It is nutritionally superior to wheat and rice with respect to protective nutrients such as dietary fibre, calcium and protein and has well balanced amino acid profile and a good source of methionine, cystine and lysine. Finger millet contains 6-8 percent protein, 1-1.7 percent fat, 65-75 percent starch, 18-20 percent dietary fiber and 2-2.5 percent minerals (Ushakumari, 2009) [13]. Generally millets inherently carry certain anti-nutritional factors to keep away the predating insects. Finger millet does contain anti-nutritional factors, which might reduce the availability of nutrients. Some of these factors present in ragi include tannins, non-starchy polysaccharides-glucans, protease inhibitors, oxalates and phytates, each of which might directly or indirectly affect the digestibility of nutrients (Kumar *et al.,* 2016) [4].
The chemical analysis revealed that finger millet is lower in protein and starch and higher in polyphenol and tannin content than pearl millet. Tannins have been reported to negatively affect the protein of flour by binding the protein so that it is not biologically available. The relatively high tannin content of red finger millet, combined with the low protein content, could significantly decrease the nutritional value of the resulting food product (McDonough *et al*., 1986). The nutrient content of food grain is relatively poor after milling but the bioavailability of certain nutrients improves considerably. Removal of complex polysaccharides of fibrous bran, tannins and phytates during milling improves the bioavailability of iron (Rao and Prabhavathi, 1978). Dehulling removes most of the phenols from finger millet grain with concomitant increase in in-vitro protein digestibility (Ramachandra *et al*., 1977) [9].
The finger millet contains relatively higher proportion of oxalic acid (46 mg/100g), which generally binds with the minerals, reduces their bioavailability and forms oxalate which very often leads to kidney stone (Ravindran, 1991) [11]. The millet also contains considerable amount of phytic acid, which is known to combine with calcium and other minerals and reduce their bioavailability. But most of the phytic acid is located in the seed coat of the millet and hence separation of the seed coat by milling (decortication) is expected to enhance the bioavailability of minerals in the decorticated millet. The determination of the proximate composition provides the base for the optimization of degree of milling that has to carry over on the millet in further studies.

However the milling of raw finger millet was not so successful so far as the millet is in fragile nature. Hence it becomes necessary to convert the grain hard enough to facilitate milling activity. Hydrothermal treatment was found to be the best method to impart rigid homogeneous nature to the grain. The present study carried out with the aim of milling the finger millet (removing seed coat) and estimating the changes in proximate composition of finger millet. The proximate contents which are determined in the present study viz. protein, fat, ash, crude fiber and calcium.

2. Material and Methods

2.1 Raw Material

Finger millet of PPR-2700 *(Vakula*) variety with membranous pericarp was dehulled in *ragi* pearler and these samples were used for further study.

2.2 Hydrothermal Treatment of Finger Millet

Hydrothermal treatment is given to the cereal grains in order to obtain maximum recovery of milled grain with minimum breakage. Some desired nutritional changes also take place during hydrothermal treatment like gelatinization of starch present in the grain. Hydrothermal treat generally involves the unit operations like soaking the grain in water, steaming the soaked grain and then drying the grain to a desired level of moisture content suitable for milling.

2.2.1 Soaking

Finger millet grains were soaked in two different temperatures with different soaking times. The first condition was at room temperature of 30 °C for 24 hours and the second one at an elevated temperature of 70 °C for 1 hour 45 minutes (Ushakumari, 2009) [13]. A water bath (M.B. Instruments, Delhi) was used for soaking finger millet at 70 °C and good quality plastic containers were used to soak the grains at 30 °C.

2.2.2 Steaming

Grains after soaking were immediately subjected to steaming at three different levels i.e. 1, 1.5 and 2 kg/cm^2. The grains were spread as thin layer in bottom of the cylindrical container which was placed in the autoclave (250 × 450 mm, Optics Technology, Delhi).

2.2.3 Drying

After steaming, finger millet grains were dried in a tray dryer (C.M. Equipment & Instruments (India) Pvt. Ltd., Bangalore). The examination of the dried finger millet for the physical features such as formation of fissures, deformation in shape, variations in size, shape and color, clearly indicated that drying the finger millet at 40 °C was most appropriate with respect to the various quality attributes suitable for milling. Accordingly, the finger millet grains were dried to average final moisture contents of 12.15% and 14.09% (w.b.). (Rajasekhar *et al*., 2018) [18].

2.3 Milling of hydrothermally treated finger millet

To obtain the finger millet product free from the seed coat, the hydrothermally treated finger millet milled using rice polisher (6704, INDOSAW, Osaw Industrial Products Pvt. Ltd., Haryana). Hydrothermally treated finger millet was fed to the rice polisher for milling. The speed of carborundum disc used for finger millet milling was maintained at 2950 rpm, by measuring with digital tachometer. Based on preliminary trials, it was found that a sample of 100 g resulted in optimum milling in the polisher. Residence time of the sample inside the polisher for milling was maintained as 20 seconds and a sample is milled in two passes rather than single pass for better milling yield.

The milled sample consists of head grain (milled), brokens and seed coat fraction. To classify these fractions sieve analysis was performed using standard sieves of 1003 µm, 600 µm sizes. The over size of 1003 µm was head grain, under size of 1003 µm and over size of 600 µm was termed as brokens and under size of 600 µm was termed as seed coat matter (Ushakumari, 2009) [13]

2.4 Proximate analysis of finger millet grain

The head grains (free from seed coat) were analysed for the proximate composition. The following standard procedures were adopted for proximate analysis of experimental finger millet samples.

2.4.1 Moisture Content

Five grams sample was weighed using a sensitive digital balance (0.001 g accuracy) (AJ-220E, Essae-TERAOKA, Pvt. Ltd. Bangalore) in a non-corrosive metal dish. The moisture content of sample was determined by hot air oven method at 105 ± 2 °C for 24 hours. The average moisture content of the samples on wet basis was calculated using the following equation and the mean of three such reading was recorded as average moisture content.

$$\text{Moisture content (\% wet basis)} = \frac{W_1 - W_2}{W_1} \times 100$$

where,

W_1= Initial weight of the sample, g
W_2= Final weight of the sample, g

2.4.2 Ash

The total ash content (mineral matter) was determined by AOAC (1980) [2] method. In a previously heated and cooled porcelain dish, about 5 g of the samples was weighed. The sample was charred carefully on a heater, and then heated in a muffle furnace maintained at 550 °C for 3 hours. Then the ash content was calculated as:

$$\text{Ash (\%)} = \frac{W_2}{W_1} \times 100$$

where,

W_1 = Weight of the sample, g
W_2 = Weight of the residue after ashing, g

2.4.3 Protein

The protein content was determined from the organic nitrogen content estimated by Micro-Kjeldahl method. An automatic Nitrogen/Protein Estimation System (KEL PLUS KES 12 L, Pelican Equipments, Chennai, India) was used for this purpose. The various nitrogenous compounds were converted into ammonium sulphate by boiling with concentrated sulphuric acid. The ammonium sulphate formed was decomposed with an alkali (NaOH) and the ammonia liberated was absorbed in excess of standard solution of acid and then back titrated with standard alkali. The nitrogen value was multiplied by 6.25 to obtain the protein content. The protein content was calculated as:

$$\text{Protein(\%)} = \frac{14 \times \text{Titre value} \times \text{Normality of HCl}}{\text{Sample weight}} \times 6.25$$

2.4.4 Fat
Fat was estimated as crude ether extract of the dry material. The dry sample (3-5 g) taken in thimble was placed in the Automatic Soxhlet Apparatus (Socsplus SCS 4, Pelican Equipments, Chennai) and extracted with petroleum benzene for about 2 h, and the flask with the residue was dried in an oven at 80-100 °C, cooled in a desiccator and weighed. The fat content was then calculated as:

$$\text{Fat content}(\%) = \frac{\text{Weight of ether extract}}{\text{Weight of sample}} \times 100$$

2.4.5 Calcium
Calcium content of sample was found titrimetrically using standard potassium permanganate solution (Nagi *et al.*, 2007) [7]. Calcium from the acid extract was precipitated as calcium oxalate and dissolved in H_2SO_4 and titrated against standard solution of $KMnO_4$. Calcium was calculated in milligram per 100 g of finger millet flour from the $KMnO_4$ used, where 1 mL of 0.1 N $KMnO_4$ is equivalent to 2 mg calcium.

$$\text{Calcium, mg /100 g} = \frac{2}{x} \times \frac{100}{25} \times \frac{100}{W}$$

2.4.6 Crude fiber
The crude fiber content of samples was estimated using the procedure described in AOAC (1960) [1]. The crude fiber content was calculated as:

$$\text{Crude fibre}(\%) = \frac{W_e - W_a}{\text{Weight of sample}}$$

where,

W_e = Pre-weighed ash, g

W_a = Weight of the dish after ashing, g

2.5 Statistical Analysis
Statistical analysis of all experimental data was carried out by following standard procedures (Panse and Sukhatme, 1985) [12]. Factorial Completely Randomised Design (FCRD) was used and the effect of different independent variables on the dependent were analysed. Statistical Package for the Social Sciences (SPSS) software was used to analyse the data.

3. Results and Discussion
3.1 Effect of hydrothermal treatment on physicochemical properties of milled finger millet
The combined effect of hydrothermal treatment and milling on finger millet grain was studied for their physicochemical properties. It has a prominence in determining the nutritional characteristics, sensory acceptability as well as handling characteristics. The results were discussed in detail in foregoing text.

3.2 Protein
Steaming pressure influenced the protein content of finger millet. In case of finger millet soaked at 30 °C, protein content decreased from 6.64 to 5.72% as the steaming pressure was increased from 1 to 2 $kgcm^{-2}$ at 12.15% (w.b.) final moisture content. Protein content decreased from 6.61 to 5.56% as the steaming pressure was increased from 1 to 2 $kgcm^{-2}$ at 14.09% (w.b.) final moisture content (Fig. 1).

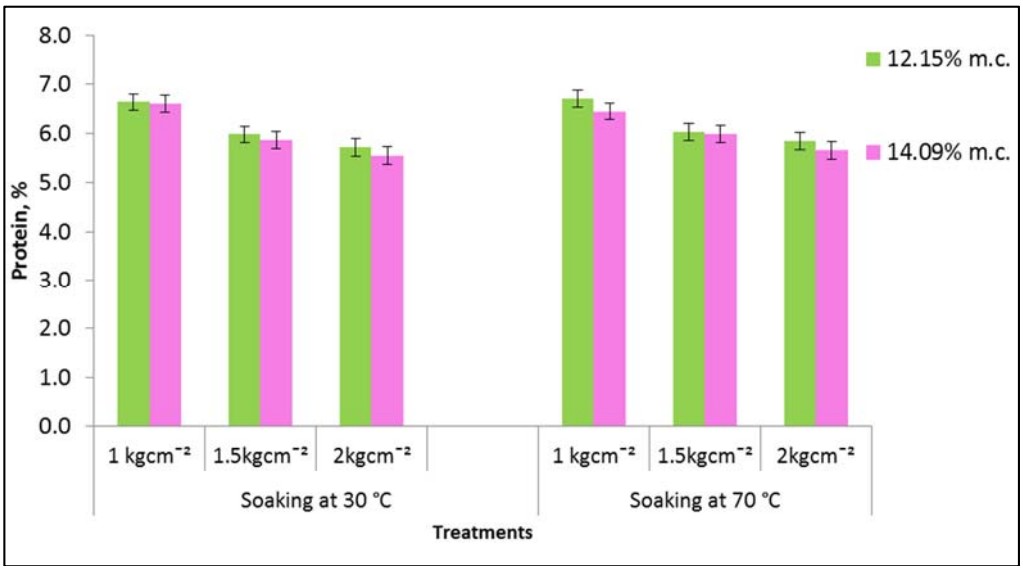

Fig 1: Effect of hydrothermal treatment and milling on protein content

Similarly in case of finger millet soaked at 70 °C, protein content decreased from 6.71 to 5.84% as the steaming pressure was increased from 1 to 2 $kgcm^{-2}$ at 12.15% (w.b.) final moisture content. Protein content decreased from 6.45 to 5.66% as the steaming pressure was increased from 1 to 2 $kgcm^{-2}$ at 14.09% (w.b.) final moisture content. Steaming pressure and moisture content significantly influence protein content of milled finger millet grains at $P<0.01$. As reported in the literature, during the parboiling process of cereals grains, the protein molecules are separated and sunk into the compact mass of gelatinized starch, becoming less liable to extraction by mechanical and thermal process (Luh, 2001) [6]. However some amount of protein situated beneath the seed coat was abraded during milling and this could be the reason for reduced protein against milling. The protein content of milled finger millet decreased with increasing steaming pressures, which implies that protein content decreases upon increasing head rice yield or as increase of degree of milling. However, the amount of decrease was considerably less as compared to the other millet grains in which milling without hydrothermal treatment is possible.

3.3 Fat
Steaming pressure influenced the fat content of finger millet. In case of finger millet soaked at 30 °C, fat content decreased from 1.02 to 0.82% as the steaming pressure was increased

from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Fat content decreased from 0.88 to 0.79% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content (Fig. 2). Similarly in case of finger millet soaked at 70 °C, fat decreased from 0.98 to 0.79% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Fat decreased from 0.87 to 0.76% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content. Steaming pressure and moisture content significantly influenced the fat content of milled finger millet grains at $P<0.01$. Millet pericarp and germ have considerable amount of lipids and hence the total lipid content and fatty acid profile can be affected by the extent of milling in millets (Liang *et al*., 2010) [5]

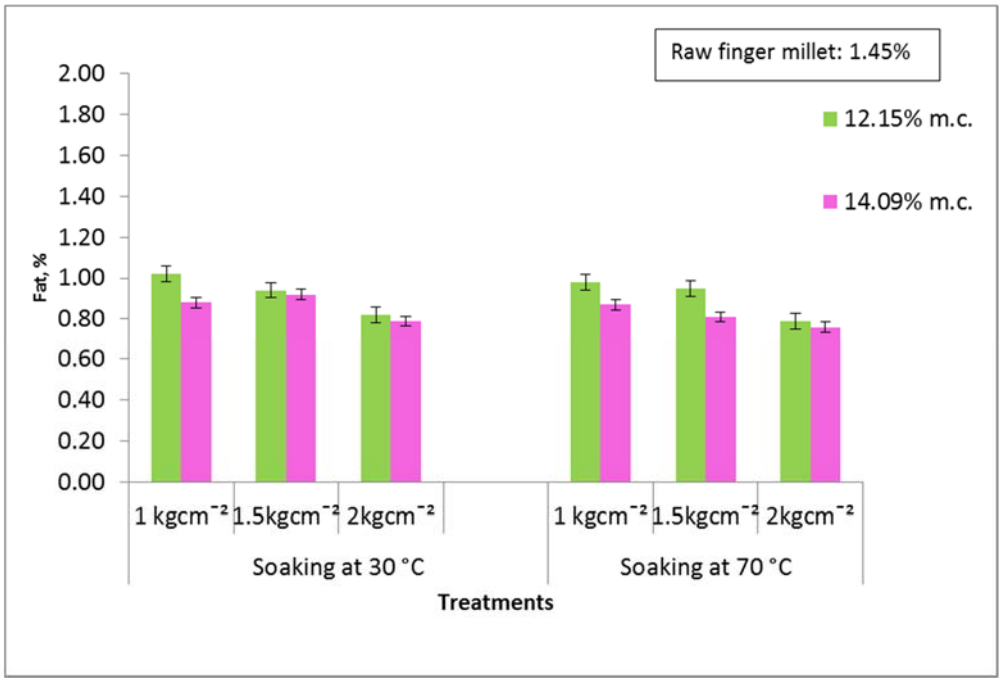

Fig 2: Effect of hydrothermal treatment and milling on fat content

3.4 Ash

Steaming pressure influenced the ash of finger millet. In case of finger millet soaked at 30 °C, ash decreased from 1.06 to 0.93% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Ash decreased from 1.02 to 0.92% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content (Fig. 3). Similarly in case of finger millet soaked at 70 °C, ash decreased from 1.10 to 0.99% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Ash decreased from 1.12 to 0.97% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content. Soaking temperature, steaming pressure and moisture content significantly influenced the ash content of milled finger millet grains at $P<0.01$.

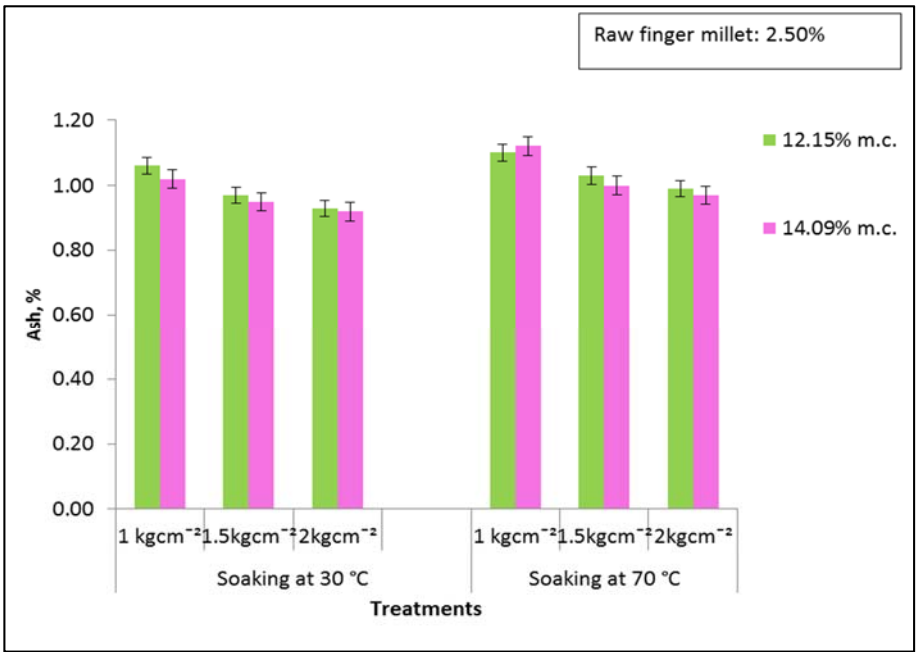

Fig 3: Effect of hydrothermal treatment and milling on ash content

3.5 Calcium

Steaming pressure influenced the calcium of finger millet. In case of finger millet soaked at 30 °C, calcium decreased from 225 to 199 mg/100 g as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Calcium decreased from 212 to 194 mg/100 g as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content (Fig. 4). Similarly in case of finger millet soaked at 70 °C, calcium decreased from 199 to 193 mg/100 g as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Calcium decreased from 204 to 187 mg/100 g as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content. Steaming pressure and moisture content significantly influenced the calcium content of milled finger millet grains at $P<0.01$. The decrease in calcium content was attributed to the extent of milling, since higher milling was reported as steam pressure was increased. As per literature, hydrothermal treatment did not cause any significant change in the nutrient content of finger millet, but milling reduced most of the nutrients (Ushakumari, 2009) [13].

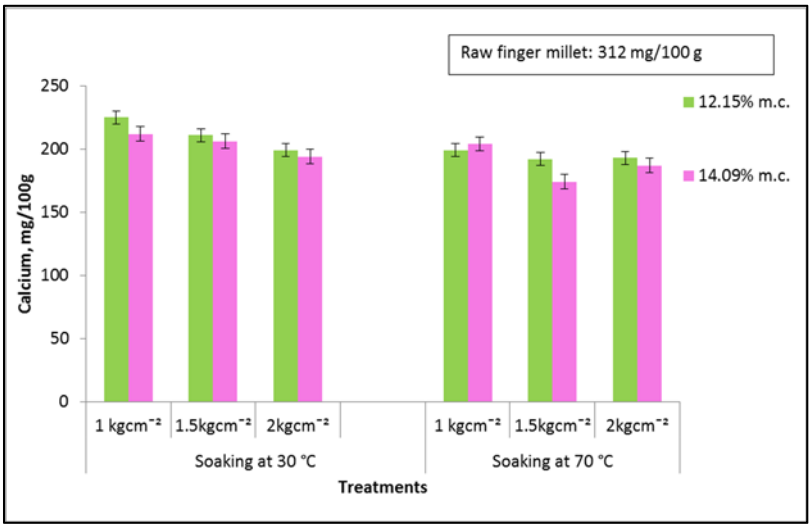

Fig 4: Effect of hydrothermal treatment and milling on calcium content

3.6 Crude Fiber

Steaming pressure influenced the crude fiber of finger millet. In case of finger millet soaked at 30 °C, crude fiber decreased from 1.75 to 1.19% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Crude fiber decreased from 1.24 to 1.02% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content (Fig. 5). Similarly in case of finger millet soaked at 70 °C, crude fiber decreased from 1.56 to 1.08% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 12.15% (w.b.) final moisture content. Crude fiber decreased from 1.38 to 1.00% as the steaming pressure was increased from 1 to 2 kgcm^{-2} at 14.09% (w.b.) final moisture content.

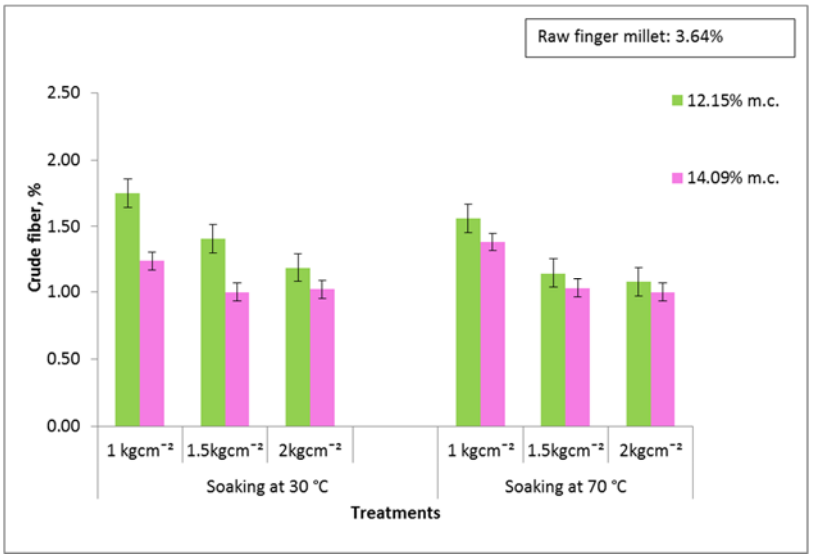

Fig 5: Effect of hydrothermal treatment and milling on crude fiber content

Steaming pressure and moisture content significantly influenced the fat content of milled finger millet grains at $P<0.01$. It was clear that the reduction in crude fibre was exclusively due to the milling performed rather than hydrothermal treatment. Results on crude fibre were not significantly different among the various soaking/steaming time combinations possibly due to the heat capacity generated being too low to cause any degradation on the fibre present (Ayamdoo *et al.*, 2015) [3].

4. Conclusions

Milled finger millet recorded lower values of protein (5.66%), fat (0.76%), ash (0.97%), calcium (187 mg/100 g) and crude fiber (1.00%) compared to the raw finger millet because of the seed coat removal. Soaking temperature, steaming pressure and final moisture content significantly influenced the output capacity of finger millet.

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