

Original Research Article

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Effect of Hydrothermal Treatment on Milling Characteristics of Finger Millet

M. Rajasekhar^{1*}, L. Edukondalu², D.D. Smith³ and G. Veeraprasad²

¹Indian Agricultural Research Institute, New Delhi, India

²College of Agricultural Engineering, Bapatla, India

³College of Food Science and Technology, Pulivendula, India

*Corresponding author

ABSTRACT

Keywords

Hydrothermal treatment, Milling yield, Broken percentage and seed coat matter

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The present study was undertaken to determine the effect of hydrothermal treatment on milling characteristics of finger millet (*PPR 2700, Vakula*). Finger millet grains were soaked in two different water temperatures of 30 °C and 70 °C with 24 and 1 hour 45 minutes soaking times respectively. Treatments were followed by steaming at 1, 1.5 and 2 kg cm⁻¹ pressures. The samples were dried at 40 °C and equilibrated to two different final moisture contents of 12 and 14% (wet basis). Hydrothermally treated samples were milled using rice polisher and the product was classified into head rice, broken and seed coat matter. From the milling studies, it was observed that the increase in soaking temperature and steaming pressure increased milling yield. Hydrothermal treatment of finger millet increased the hardness of the grain and this resulted in improved milling yield upon milling. The treatment with soaking temperature of 70 °C, steaming pressure of 2 kg cm⁻² dried to a final moisture content of 14% was found to be the best with milling yield, broken percentage and seed coat percentage of 87.80%, 4.44% and 7.68% respectively.

Introduction

Finger millet is the important minor millet which contains high amounts of calcium and other minerals as compared to other cereals. The main constituents of the millet kernel are seed coat (testa), embryo and endosperm (Chandra *et al.*, 2006). Finger millet usage is restricted due to their culinary properties and the form of availability limiting to prepare fewer products only. The main reason for this limited use is its seed coat being associated with grain (Dharmaraj *et al.*, 2013). Though there is some useful ingredient present with

the seed coat like dietary fibre, the much portion of seed coat also contains the anti-nutritional factors like tannin, saponins and polyphenol.

These factors in turn fetch the whole mass off flavoured and bad odour and appearance, which is usually being unacceptable by the new generation people. In addition to this currently the finger millet is being available in the whole flour form including the powdered seed coat matter within it. Finger millet is normally consumed in the form of flour-based foods such as *roti* (unleavened pancake),

mudde (stiff porridge/dumpling) and *ambli* (thin porridge) (Malleshi *et al.*, 2007).

In the present study more emphasis was given to change the form of finger millet in order to make it available for preparation of novel food product such as milled finger millet grain (hereafter it denotes the grain without seed coat or testa). Generally the grain finger millet contains an intact seed coat or testa with its endosperm matter. Whenever efforts were kept to remove this seed coat the grain gets pulverised including with seed coat and results in formation of whole flour, which was mainly due to the fragile nature of the finger millet. Hence it becomes necessary to change the fragile nature of the finger millet grain to harder one in order to make any mechanical processing operations over the grain. The experiment focuses on imparting harder texture to the grain through subjecting them to hydrothermal treatment and to convert the total grain matter into compact homogeneous gelatinized mass. The hydrothermally treated grains possess harder texture are less susceptible to breakage during milling operation consequently the seed coat matter only get abraded from the surface. Hence, the main objective of this study was to determine the effect of soaking temperature and steaming pressure on milling characteristics of finger millet.

Materials and Methods

Finger millet of PPR-2700 (*Vakula*) variety was used for milling. Finger millet grains with membranous pericarp were dehulled in *ragi* pearler at Post Harvest Technology Centre, Bapatla and these samples were used for further study.

Hydrothermal treatment of finger millet

Finger millet grains were soaked in two different temperatures of 30 °C and 70 °C

with 24 and 1 hour 45 minutes soaking times respectively (Ushakumari, 2009). 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. Grains after soaking were immediately subjected to steaming at steaming pressures of 1, 1.5 and 2 kg/cm² in order to get the grains completely gelatinized. 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). After steaming, finger millet grains were dried in a tray dryer [C.M. Equipment & Instruments (India) Pvt. Ltd., Bangalore]. The preliminary experiments on drying conditions of the material were aimed at preparation of the milled finger millet. 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 steamed finger millet was dehydrated at 40 °C. The finger millet grains were dried to average final moisture contents of 12.15% and 14.09% (w.b.). The grain moisture content was measured with the electronic moisture meter (AG-QMT, LCGC Bio Analytic Solutions LLP) and the samples were removed from the dryer after reaching required moisture content.

Various combinations of soaking, steaming and drying (treatments along with the control) are shown in Tables 1 and 2.

Milling of hydrothermally treated finger millet

The milled finger millet is totally a new and novel product from the finger millet and the information on its preparation as well as its functional properties is scanty. Hence, in the present study the finger millet was

hydrothermally treated and then milled using rice polisher (6704, INDOSAW, Osaw Industrial Products Pvt. Ltd., Haryana). The flow chart of preparation of milled finger millet from hydrothermally treated finger millet grains was shown in figure 1. 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. 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.

Classification of milled Sample

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). The terminology related to the classified milled sample is discussed below.

Milling yield

Milling yield in percent is defined as the ratio of the mass of the head grain to that of the total sample (Dharmaraj *et al.*, 2013) and is expressed as:

$$\text{Milling yield (\%)} = \frac{\text{Weight of head grain}}{\text{Weight of total sample}} \times 100$$

Broken percentage

It is defined in percentage as the ratio of broken grains to the total sample (Ushakumari, 2009) and is expressed as

$$\text{Broken percentage (\%)} = \frac{\text{Weight of brokens}}{\text{Weight of total sample}} \times 100$$

Seed coat percentage

It is defined in percentage as the ratio of seed coat matter to the total sample (Ushakumari, 2009) and is expressed as

$$\text{Seed coat percentage (\%)} = \frac{\text{Weight of seed coat}}{\text{Weight of total sample}} \times 100$$

Degree of milling

The degree of milling is the percentage of the grain removed mainly in the form of seedcoat during milling. The degree of milling is calculated as ratio of seed coat matter plus broken to the total sample fed to the polisher.

Output capacity

Output capacity in kg h^{-1} is calculated as mass of milled finger millet achieved per unit time.

Statistical analysis

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.

Results and Discussion

Effect of hydrothermal treatment on milling characteristics of finger millet

Effect of soaking and steaming conditions on milling yield

As the steaming pressure was increased, milling yield also increased. In case of finger millet soaked at 30 °C and steamed at 2 kg cm^{-2} , highest milling yields recorded was 78%

and 86.23% at 12.15% and 14.09% moisture contents, respectively. Similarly, finger millet soaked at 70 °C and steamed at 2 kg cm⁻², recorded highest milling yields of 81.16% and 87.88% at 12.15% and 14.09% moisture contents, respectively.

Milling yield varied significantly (at P<0.01) with grain soaking temperature, grain steam pressure and moisture content of grain at the time of milling. From the results shown in figure 2, an increase in soaking temperature and steaming pressure increased milling yield. Hydrothermal treatment of finger millet increased the hardness of the grain and this resulted in improved milling yield upon milling. Besides, moisture content of the grain also influenced the milling yield. Finger millet milled at 12.15% moisture content resulted in less milling yield compared to grains milled at 14.09%. It was observed that the higher moisture content (14.09%) facilitated the leathery nature to the seed coat and hence seed coat was easily abraded from the grain.

Effect of soaking and steaming conditions on broken percentage

Broken percentage of milled finger millet (MFM) decreased from 25.43% to 12.71% and from 15.42% to 6.63% at 12.15% and 14.09% moisture contents respectively with increase in steam pressure, in case of grains soaked at 30 °C. The broken percentage of milled finger millet (MFM) decreased from 20.66% to 9.42% and from 9.52% to 4.44% at 12.15% and 14.09% moisture contents respectively with increase in steam pressure, in case of grains soaked at 70 °C.

As the steaming pressure was increased, broken percentage decreased. In case of finger millet soaked at 30 °C and steamed at 2 kg cm⁻², lowest broken recorded were 12.71% and 6.63% at 12.15% and 14.09% moisture contents respectively. Similarly, finger millet

soaked at 70 °C and steamed at 2 kg cm⁻², recorded lowest broken percentage of 9.42% and 4.44% respectively at 12.15% and 14.09% moisture contents. The property of raw finger millet called brittleness or floury endosperm disappeared after hydrothermal treatment and the breakage was arrested to the great extent.

The broken percentage decreased as the soaking temperature, steaming pressure and moisture content was increased. Soaking temperature, steaming pressure and moisture content significantly influenced broken percentage at P<0.01. From the figure 3 it was clear that the increase in steam pressure improved the hardness of the grain and the broken percentage was inversely proportional to the hardness of the grain. The higher moisture content of the grain reduced the broken percentage as it rendered the seed coat leathery on the grain surface during milling, which enabled easy milling of seed coat without breakage of grain.

Effect of soaking and steaming conditions on seed coat percentage

The complete milling of grain was achieved only when the total seed coat matter was separated to its full extent, hence it could be inferred that the higher amount of seed coat generated was an indication of higher milling and vice-versa.

But it was also clear that sometimes small amount of endosperm matter also milled and associated with the seed coat matter.

Seed coat separation increased with increase in soaking temperature, steaming pressure and moisture content. The seed coat percentage increased from 4.22% to 9.29% and from 5.22% to 7.14% at 12.15% and 14.09% moisture contents, respectively with increase in steam pressure, in case of grains soaked at 30 °C.

Table.1 Hydrothermal treatments of finger millet grains soaked in water at (30 °C) for 24 h

Treatments	Soaking		Steaming		Final moisture content of dried finger millet (% w.b.)*
	Temperature °C	Time h	Pressure kg cm ⁻²	Time min	
T1	30	24	1	20	12.19±0.36
T2					14.18±0.27
T3			1.5	18	12.11±0.26
T4					14.14±0.25
T5			2	16	12.10±0.22
T6					13.89±0.39

Table.2 Hydrothermal treatments of finger millet grains soaked in water at (70 °C) for 1.45 h

Treatments	Soaking		Steaming		Final moisture content of dried finger millet (% w.b.) *
	Temperature, °C	Time, h	Pressure, kg cm ⁻²	Time, min	
T7	70	1.45	1	20	12.21±0.19
T8					14.08±0.17
T9			1.5	18	12.07±0.16
T10					14.09±0.20
T11			2	16	12.07±0.17
T12					14.05±0.22
T _c	Raw finger millet (RFM) / Control sample				11.50±0.06

*The mean value ± Standard deviation

Fig.1 Flow chart for preparation of hydrothermally treated and milled finger millet

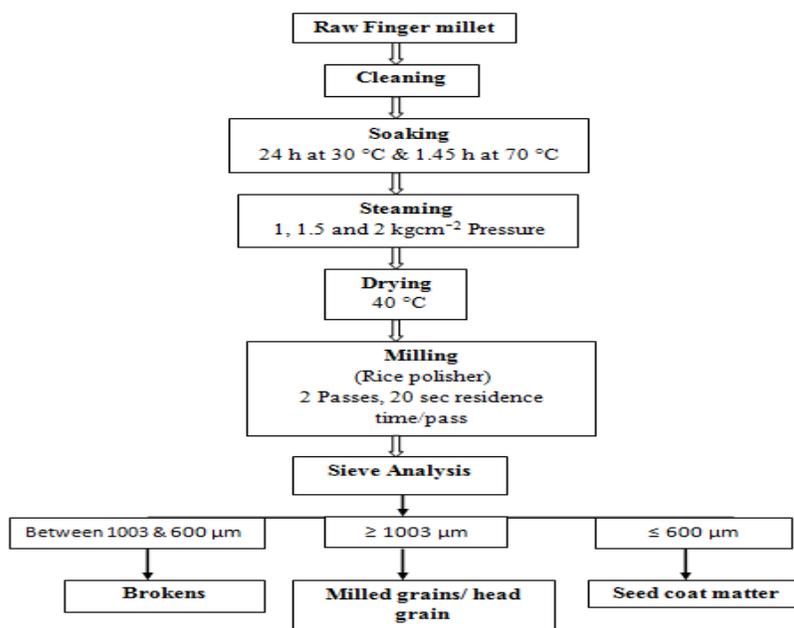


Fig.2 Effect of soaking and steaming conditions on milling yield

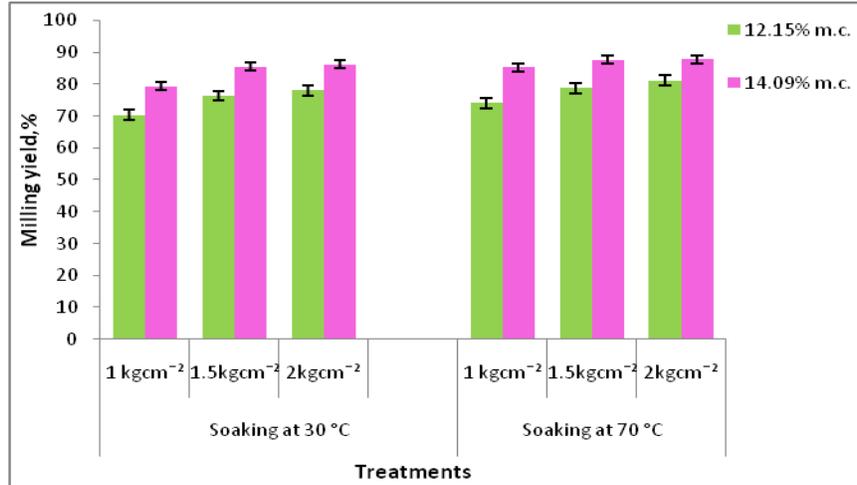


Fig.3 Effect of soaking and steaming conditions on broken percentage

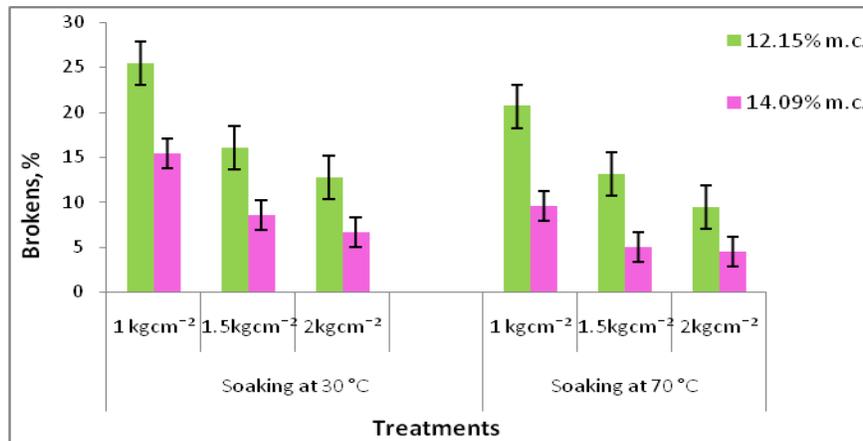


Fig.4 Effect of soaking and steaming conditions on seed coat percentage

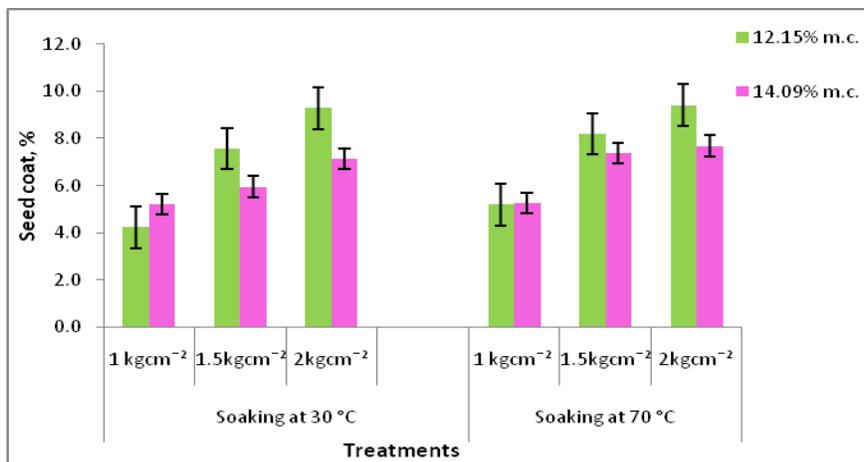


Fig.5 Effect of hydrothermal treatment on degree of milling

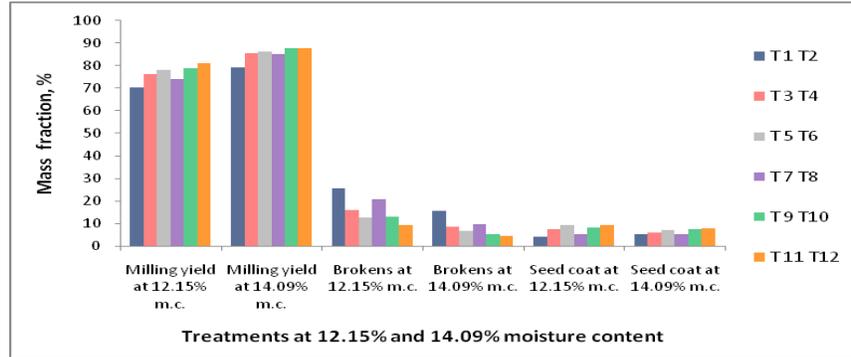
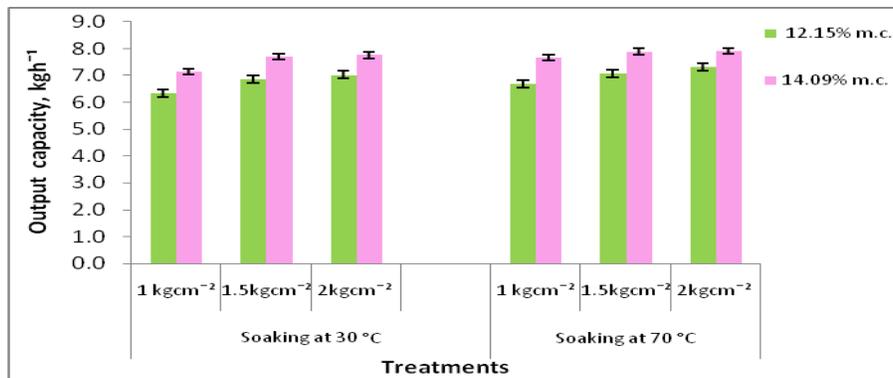


Fig.6 Effect of hydrothermal treatment on output capacity of the polisher



The seed coat percentage increased from 5.20% to 9.42% and from 5.26% to 7.68% at 12.15% and 14.09% moisture contents, respectively with increase in steam pressure, in case of grains soaked at 70 °C (Fig. 4). The reason for the increased seed coat could be due to an increased hardness upon increased steam pressures, which enabled more milling and hence the seed coat was produced in the same amount. Seed coat percentage varied significantly with the changes in soaking temperature, steaming pressure and moisture content at $P < 0.01$.

Degree of milling

The degree of milling is the percentage of the grain removed mainly in the form of seedcoat during milling (Shobana and Malleshi, 2007). The optimum conditions for high degree of milling were determined with treatment

corresponding to high milling yield, lower broken percentage and higher seed coat matter together.

Treatment No. 12 with soaking temperature of 70 °C, steaming pressure of 2 kg cm⁻² dried to a final moisture content of 14.09% was the best among all (Fig. 5).

Effect of pre-treatment conditions on the output capacity of the polisher during milling

To calculate the output capacity of the polisher, 100 g of HTM was taken and the polisher was run for 20 seconds. Milling was done in two passes rather than single pass for better milling yield. Output capacity increased with increase in soaking temperature, steaming pressure and moisture content.

The output capacity increased from 6.33 to 7.02 kg h^{-1} and from 7.14 to 7.76 kg h^{-1} at 12.15% and 14.09% moisture contents respectively, with increase in steam pressure, in case of grains soaked at 30 °C. Output capacity increased from 6.67 to 7.30 kg h^{-1} and from 7.67 to 7.91 kg h^{-1} at 12.15% and 14.09% moisture contents respectively with increase in steam pressure, in case of grains soaked at 70 °C (Fig. 6).

Milling characteristics of the hydrothermally treated millet were influenced by the grain hardness. The increase in soaking temperature and steaming pressure increased milling yield. Hydrothermal treatment of finger millet increased the hardness of the grain and this resulted in improved milling yield upon milling. Finger millet milled at 12.15% moisture content resulted in less milling yield compared to grains milled at 14.09%.

It was observed that the higher moisture content (14.09%) facilitated the leathery nature to the seed coat and hence seed coat was easily abraded from the grain and also the same conditions or feature attained facilitated the less breakage of grain. Seed coat separation increased with increase in soaking temperature, steaming pressure and moisture content.

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