Effect of soaking and malting on finger millet (*EleusineCoracana*) grain

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Abstract: Hydration characteristics of finger millet were investigated at different temperatures of 30, 40, 50 and 60℃. The experimental data was fitted with Peleg model. The Peleg rate constant K_1 was 0.0063 to 0.0010 h%$^{-1}$. It is observed that K_1 decreases with increasing temperature (30-60℃) and Peleg capacity constant K_2 was 0.0022 to 0.0012 %$^{-1}$. It was observed that K_2 decreases with increasing temperature (30-60℃). The activation energy was in the range of 1.9-7.2 MJ mol^{-1} and decreased with increasing temperature(30-60℃). Finger millet malt was prepared at various germination times 8, 12, 16, 20 and 24 h. As germination time increases, the protein content also increases. The protein content was in the range of 14% -17.5%.

Keywords: soaking, Peleg model, water absorption, malting, protein content

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1 Introduction

Finger millet (*Eleusinecoracana*) also known as *ragi*, *nachani* or *nagli*, is one of the important millet in India. The annual production of finger millet is 2.8 million ton with productivity of around 1,500 kg ha^{-1}. Finger millet, extensively grown on hilly areas and southern part of India and is widely consumed in the form of dumping by vast section of people. (Vidyavatiet al., 2004). Finger millet is a rich source of Ca (300-350 mg/100 g), Phosphorus is 283 mg/100 g and Fe 3.9%. (Gopalan et al., 2000). The finger millet has a well-balanced amino-acid profile and is a good source of methionine, cystine and lysine. These essential amino acids are of special benefit to those who depend on plant food for their protein nourishment (that is most of Indian people). It also contains about 72% carbohydrates, a high proportion of which is in the form of non-starchy polysaccharides and dietary fiber, which helps in constipation, and lowering of glucose in blood. It is a rich source of vitamins viz. thiamine, riboflavin, folic acid and niacin (Vidyavatiet al., 2004). Finger millet isan important millet and its malting has been practiced both at household and industrial level in India and some of the African countries. Generally, the finger millet seeds are cleaned and steeped for 24 h, thengerminated under controlled condition on moist cloth at room temperature up to 24 h. Germinated seeds are taken out every 24 h and dried at 50℃ in an air oven for 12 h and vegetative growth portion to be removed by gentle brushing (manually) andto be ground for malting. Malted ragi flour, or extract derived from it, is extensively used in preparation of weaning and infant foods, beverages or other pharmaceutical preparations (Nirmalaet al., 2000). The main purpose of malting is to produce enzymes and to breakdown cell walls surrounding starch granules. One of the most important physico–chemical changes that occur during malting is the degradation of the proteinaceous matrix that surrounds the starch granules within the cells of the endosperm and their conversion into soluble peptides and amino acids to provide

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substrates for the synthesis of proteins in the growing embryo (Enejeet al., 2003).

Turhanet al. (2002) studied water absorption in chickpea during soaking between temperature of 20 and 100℃. Soaking is the first step during manufacture of edible chickpea. The principal reason of soaking is to gelatinize the starch into the grain. They showed that Peleg model can be used to describe water absorption of chickpea during soaking. The Peleg rate constant K_1 related to the water absorption capacity and the Peleg capacity constant K_2 related to the maximum attainable moisture content. The results showed that K_1 decreases with increasing temperature i.e.increasing waterabsorptioncapacity with increasing temperature. The K_2 increases or decreases with increasing temperature depending on the sample and method of moisture content calculation used.

The variation in free sugars and non-starch polysaccharides in finger milletgrain was observed upon germination (Nirmalaet al., 2000). The changes in carbohydrates, free amino acids, organic acids, phytate and HCL– extractable minerals during germination and fermentation have been reported (Nirmalaet al., 2000).

Water temperature amongst other factors influences the absorption of moisture into the grain during soaking. Various scientists have studied the soaking and malting characteristics of maize and wheat grains (Enejeet al., 2003, Suhasiniet al., 1997). Since finger millet was used in ragi-based product like ragi malt puff, bhakri, bread and cookies, it is necessary to know the information about hydration kinetics and malting of finger millet grain. Considering all the points discussed as above, the present study had been undertaken with the following objectives to study: i) the soaking characteristics of finger millet grain. ii) the changes in protein content of finger millet malt during soaking and malting.

2 Materials and methods

2.1 Soaking

For soaking and malting, the finger millet variety was *Dapoli*–1. It was brought from research farm of Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The moisture content of the finger millet grain was 13.72 (% w.b.). About 15 g finger millet grain was taken in a 50 mLtest tube containing 1:3 (45 mL) of distilled water. The experiment was performed at temperatures of 30℃, 40℃, 50℃ and 60±1℃. Test tubes were placed in a constant temperature water bath at the experimental temperatures with an error of ±1℃. Samples were taken out from the constant temperature water bath at 5 min intervals during initial first hour and after that samples were taken out at 15 min interval. Around 25 test tubes were used for one replication. The experiment was replicated three times. The total number of test tubes required was 75. The surface water of soaked grains were removed by filtering through a coarse filter cloth followed by placing onto two layers of blotting paper quickly. The weight of soaked grain was determined with the help of Electronic Weighing balance (Make CONTECH) with least count 0.01 g. The experiment was performed until the moisture content attained as equilibrium moisture content. The constant readings were observed until the fiveconstant reading and reported a first value.

The water uptake was calculated as Peleg (1988);

$$\text{Water uptake}(\%) = \frac{W - W_0}{W_0} \times 100 \quad (1)$$

where, W_0 = Initial weight, g; W = Final weight aftermoisturegain, g.

2.2 Theoreticalconsiderations

Peleg (1988) proposed a simple, empirical equation not derived from any set of physical laws or diffusion theories, to model water absorption of food materials. The model has been to predict long- range moisture absorption from experiment data over a short time.

$$M_t = M_0 + \frac{t}{K_1 + K_2 t} \quad (2)$$

where, M_t = Moisture content(w.b.) after time t, %; M_0 = Initial moisture content (w.b.), %; K_1 = Peleg rate constant, h $\%^{-1}$; K_2 = Peleg capacity constant, $\%^{-1}$.

Rearranging the Equation (2) gives

$$\frac{t}{M_t - M_0} = K_1 + K_2 t \quad (3)$$

This implies plot $t/(M_t - M_0)$ against t is straight line with K_1 as ordinary intercept and K_2 the gradient of line. The Arrhenius equation could be used to describe the

temperature dependence of the reciprocal of the K_1 can be represented as

$$\frac{1}{K_1} = K_0 \exp\ (-E_a / RT) \quad (4)$$

where, *Ea* = Activation energy, kJ mol^{-1}.

2.3 Malting

The finger millet sample around 1,250 g was used in this study. The sample was divided into five equal parts (250 g) and steeped at room temperature for 4 h. After steeping, samples were germinated at room temperature for 24 h in a moist cloth. Samples were removed from moist cloth at 8, 12, 16, 20 and 24 h respectively for germination and placed in a hot air oven at 50℃ for 12 h. Vegetative growth portion were removed by gentle brushing (manually). De-vegetated seeds were weighed, powdered and used for chemical analysis. Figure 1 shows the process for preparation of finger millet malt. Figures2-6 shows the germinated finger millet at 8, 12, 16, 20 and 24 h respectively.

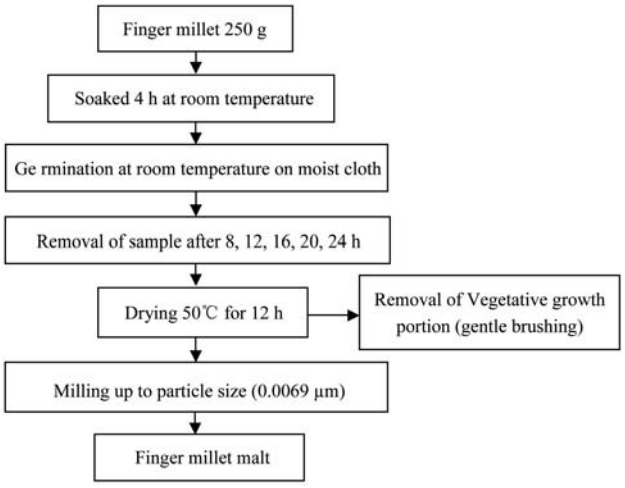

Figure 1 Process for preparation of finger millet malt

Figure 2 Finger milletgerminated for 8 h

Figure 3 Finger millet germinated for 12 h

Figure 4 Finger millet germinated for 16 h

Figure 5 Finger millet germinated for 20 h

Figure 6 Finger millet germinated for 24 h

2.4 Protein content of finger millet malt

The protein content of the finger millet malt was performed by AOAC (1990). Pipette 10 mL of digested material (3 g Sample +15 mL H_2SO_4 solution) was put into the test tube and placed at the one end of the Knjal apparatus and was added 10 mL distilled water. In to the solution 40% Sodium hydroxide (15 mL) was added. In a beaker of a Knjal apparatus take 2% boric acid (20 mL) solution and 4-5 drops of mixed indicator was added and place it under condenser. The test tube was heated at 169℃ for 5 min after making required concentration. The end point of the test was confirmed by changing the colour of the solution in a beaker from faint reddish to green, at this point the distillation process was stopped. Then the solution from the beaker was titrated against 0.02 N, H_2SO_4 till green colour changes to the faint reddish. The burette reading was recorded. The percentage (%) was estimated by using following Equations (5) and (6).

$$\text{Nitrogen \%} = \frac{(\text{Sample titre} - \text{Blank titre}) \times \text{Normality of } H_2SO_4 \times 14 \times 100}{\text{Weight of the sample} \times 1000} \quad (5)$$

Then the protein content was calculated by using relationship (6)

$$\text{Protein \%} = \text{Nitrogen \%} \times 6.25 \quad (6)$$

3 Results and discussion

3.1 Soaking

The plots of absorbed water against time for finger millet grain (for soaking study) at the four temperatures showed the characteristic moisture sorption (Figure 7), an initial high rate of moisture absorption followed by slower absorption in the latter stages. Resio *et al.* (2006) published similar curves for amaranth grain. Effect of temperature was also agreed with these studied (Bello et al., 2004; Resioet al., 2006). The higher the temperature, the more the water absorption because of increase in water diffusion rate. Curves indicated that as soaking time increased absorbed water increased and reached a saturation point and after that it had a constant value (points not shown). The constant moisture content reading was observed for continuous five points and arrived the conclusion that the saturation level has reached. The increase in temperature of the soaking reduced the soaking time.

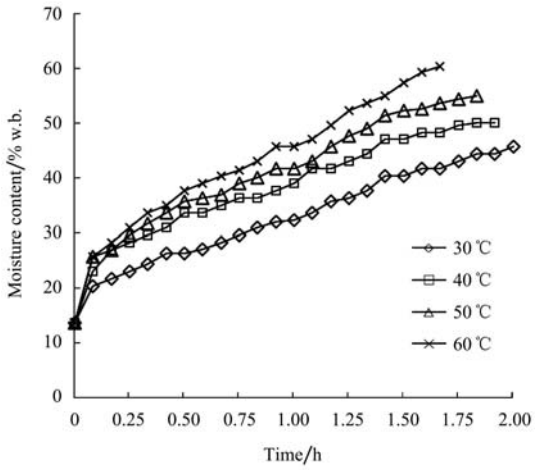

Figure7 Hydration characteristics of finger millet grain at various temperatures

Peleg's equation was applied to the experimental data with the curvilinear segment of the curve (Figure 7). Table 1 shows the regression equations obtained by fitting the data water absorption at different time intervals at a particular temperature in Peleg's equation. The correlation coefficient (R^2) ranged from 0.96-0.99 indicating that the equation adequately described sorption behavior of finger millet grain at four temperatures. Table 2 represents the values of K_1 and K_2 constants of the peleg model which was fitted to the experimental data at various temperatures i.e. 30, 40, 50 and 60℃.

Table 1 Regression analysis using Pelegs equation fitted to the experimental data

Temperature/℃	Regression equation	R^2
30	$M_t = M_0 + \frac{t}{0.0063 + 0.0022t}$	0.98
40	$M_t = M_0 + \frac{t}{0.0015 + 0.0017t}$	0.99
50	$M_t = M_0 + \frac{t}{0.0013 + 0.0014t}$	0.98
60	$M_t = M_0 + \frac{t}{0.0010 + 0.0012t}$	0.96

Table 2 Peleg rate constant K_1 and Peleg capacity constant K_2 for water absorption of finger millet

Temperature /℃	K_1/h%$^{-1}$	K_2/%$^{-1}$	R^2
30	0.0063	0.0022	0.98
40	0.0015	0.0017	0.99
50	0.0013	0.0014	0.98
60	0.0010	0.0012	0.96

Performance of Peleg model in estimating moisture content: Figure 8 shows a plot of $t/(m-m_0)$ (h %$^{-1}$) verses time (h) for finger millet grain at various temperature 30, 40, 50 and 60℃. The Peleg model gave a perfect fit during first 5 h of soaking period. The results obtained (by Turhanet al., 2002 and Resioet al., 2006) are in agreement with these results. Table 1 shows the regression equation of the Pelegs model which was fitted to the experimental data at various temperatures. Pelegs model gives a linear relationship with the time (h). The regression coefficients are also given in the Table 3.

Table 3 Regression Equations for $t/(m-m_0)$ vs.Temperature of soaking of finger millet grains

Temperature/℃	Regression Equation	R^2
30	$t/(m-m_0)=0.011\times T+0.016$	0.92
40	$t/(m-m_0)=0.009\times T+0.009$	0.96
50	$t/(m-m_0)=0.007\times T+0.008$	0.94
60	$t/(m-m_0)=0.005\times T+0.007$	0.93

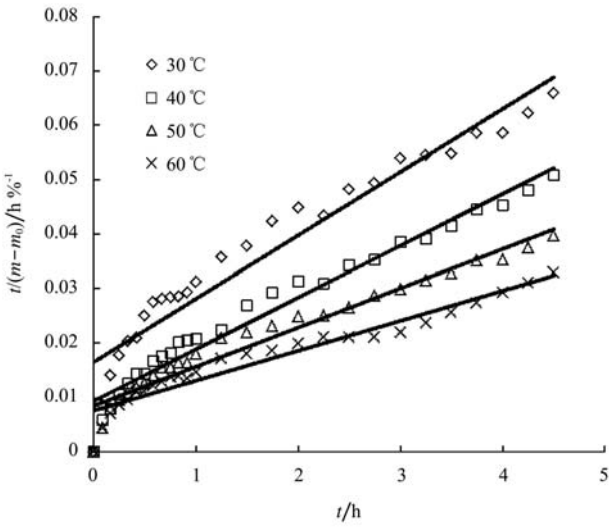

Figure 8 Fitting of Peleg model to water absorption data

Effect of temperature on K_1: it can be observed from Table 2 that K_1 decrease with temperature. These results are agreement with finding of Turhanet al. (2002) for chickpea, Resioet al. (2006) for amaranth grain. The K_1 decreased from 0.0063 to 0.0010 as temperature increased from 30 to 60℃ suggesting the corresponding increase in the initial water absorption rate. The Arrhenius type equation was used to define relationship between K_1 and temperature. Temperature of soaking is inversely proportional to the K_1 value which confirms the result of Turhanet al. (2002). Arrhenius model (Equation (4)) was fitted to the observed values of K_1 and the temperature from Table 2 to establish the relationship between K_1 and temperature. The constants were determined from the Equation (4), i.e. K_0, E_a. The observed relationship is presented in Equation (7).

$$\frac{1}{K_1}=4\times10^{10}\exp\ (-48121.43/8.314\times T)\quad r^2=0.803 \quad (7)$$

From Figure 9, value of K_0 and E_a was calculated by fitting Equation (4) to the values of K_1 and the Temperatures (T). The value of activation energy was 48.121 kJ mol^{-1}.

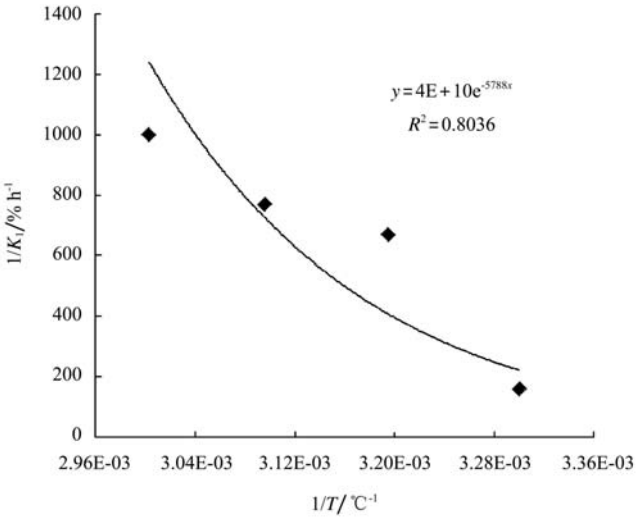

Figure 9 Arrhenius plot for the Peleg rate constant K_1 during Soaking of Finger millet

Effect of temperature on Peleg capacity constant K_2: Figure 10 shows the effect of temperature on K_2. It was observed that as the temperature increasedfrom 30 to 60℃ the K_2 decreasedfrom 0.0022 to 0.0012 linearly. Equation (8) represented the relationship of K_2 w.r.t. temperature (T). The K_2 is related to the maximum water absorption capacity. As temperature increases K_2 decreases i.e. lower the K_2, higher the water absorption capacity. As soaking temperature increased the equilibrium moisture content was also increased. It may be due to the enhanced plasticity of grain cells at higher temperature during soaking. Therefore, grain imbibed more water at higher temperature. Maskan (2002), Turhan et al. (2002), and Resioet al. (2006) found the K_2 values for wheat, chickpea and amaranth grain to decrease with increasing temperature.

$$K_2=-3\times10^{-05}T+0.0031\quad r^2=0.950 \quad (8)$$

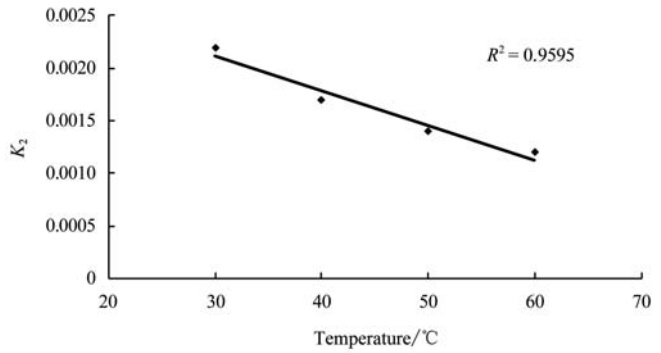

Figure 10 Effect of temperature on the Peleg'scapacity constant K_2 for finger millet

3.2 Malting

As germination time increases from 8 to 24 h, the protein content of finger millet malt increases from 14% to 17.5%. Figure 11 shows the protein content of finger malt. As the germination period increases from 8 to 24 h the protein content of the malt increases from 14.7% to 17%. The malt prepared at 24 h germination time has highest protein content. The regression analysis of germination time (h) w.r.t. protein content (%) of the malt shows that there exists a linear relationship. Equation (9) shows the between the protein (P) content w.r.t. germination time (T).

$$P = 0.15T + 13.6 \qquad r^2 = 0.970 \tag{9}$$

Correlation between the soaking time, germination time and temperature, Peleg constant K_1 and K_2 with malting of finger millet: as the soaking temperature increases from 30 to 60℃ the soaking time reduces from 4 to 3 h. The Peleg's rate constant K_1 decreased exponentially from 0.0063 to 0.0010. The capacity constant K_2 decreased linearly with increasing in the temperature. The germination of finger millet was more at 24 h of germination time whenthe protein content was reportedly as high as 17.5%.

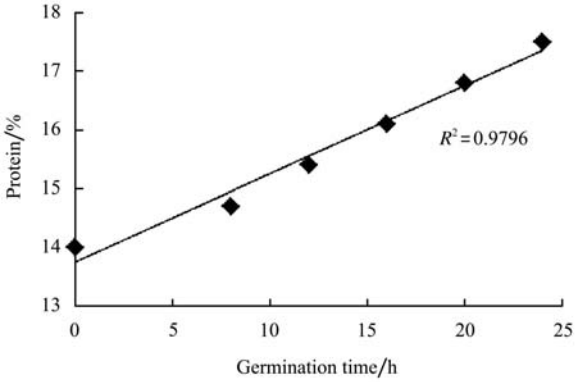

Figure 11 Effect of germination time on protein content of finger millet malt

5 Conclusions

Following conclusions could be drawn from the above mentioned study:

1) The moisture absorption was constant at 4 h, 3.45, 3.30, 3.0 h in 30, 40, 50, and 60℃, and the moisture absorption was 45.72%, 51.05%, 56.39%and 60.34% (w.b.) respectively (30-60℃).

2) The Peleg rate constant (K_1) was 0.0063-0.0010 (h%-1). K_1 was found to decrease exponentially with increasing temperature (30-60℃).

3) The Peleg capacity constant (K_2) decreases linearly from 0.0022-0.0012 (%$^{-1}$) with increasing temperature (30-60℃).

4) Activation energy was 48.121 kJ mol^{-1}.

5) As germination time increases, the protein content also increases. The protein content was in the range of 14% -17.5 % as germination time increase from 8 to 24 h.

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