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Research Paper :

Study on effect of milling on quality and nutritive value of finger millet flour (*Eleusine coracana*)

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ABSTRACT

Fineness modulus of flour increased with the increase in plate clearance. As the feed rate and plate speed increased upto an optimum level, the fineness modulus decreased and further increase in feed rate and plate speed, increased the fineness modulus. Fineness modulus increased from 2.04 to 3.44 and 2.05 to 3.45 with the increase in plate clearance from 0.3 to 0.7 mm for the ragi flour from varieties GPU-28 and L-15, respectively. The least fineness modulus was recorded at 0.3mm clearance followed by 0.5 mm. Fineness modulus decreased from 2.18 to 2.04 and 2.21 to 2.05 with the increase in feed rate and attained the least value at a feed rate of about 100 kg/h for GPU-28 and L-15 ragi flours. Beyond this, the fineness modulus increased as the feed rate increased. Fineness modulus decreased from 2.36 to 2.04 and from 2.37 to 2.05 as the plate speed increased from 450 rpm to 600 rpm and it increased with further increase in plate speed in case of both the varieties of ragi. The fineness modulus recorded the least values of 2.04 and 2.05 at 600 rpm plate speed for GPU-28 and L-15 varieties ragi flour, respectively. Loss of calcium from 0.53 to 0.33 per cent phosphorus from 0.25 to 0.22 per cent and protein from 11.45 to 10.35 per cent was recorded with the decrease in plate clearance from 0.7 to 0.3 mm for GPU-28 ragi flour. The minimum loss recorded was at 0.7 mm clearance followed by 0.5 mm. Calcium, phosphorus and protein values reduced from 0.49 to 0.33, 0.25 to 0.16 and 11.62 to 10.29 per cent for GPU-28 flour, respectively as the plate speed increased from 450 to 700 rpm. The maximum reduction was noted at 700 rpm plate speed compared to 600 and 450 rpm.

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Key words : Fineness modulus, Plate clearance, Plate speed, Feed rate

Ragi is a staple and prime food for farming communities. It is a rich source of calcium (344 mg/100 g seeds), phosphorus (283 mg/100 g seeds), thiamine (420 mg/100g seeds) with 100 per cent edible matter. In traditional dietaries, it is consumed in the form of dumplings (ragi balls) by using flour. Some varieties of ragi possess very good malting qualities almost nearing the level of barley. It is also good for infants and diabetic patients.

Dohiya and Kapoor (1983) studied the effect of storage conditions on the protein quality of pearl millet flour. Whole grain flours of two high yielding varieties (HC6 and HC 7) of pearl millet were stored in polythene bags, earthen pots and gunny bags for 10 and 20 days at ambient temperature of 20-27^0 C with 60-70 per cent RH. During storage, moisture content increased where as total protein did not change. Protamines and glutamines were the major proteins constituting 63 per cent of total protein. The different protein fractions were not affected by storage conditions. Amounts of tryptophan, methionine, total and available lysine decreased during storage. Maximum decrease in protein quality was found in HC6 stored in gunny bags.

Chaudhary and Kapoor (1984) reported the nutritional value of pearl millet flour stored in polythene bags, tin cans, gunny sacks and earthern pots at 20—25^0 C and 60-65 per cent RH. During storage, the highest increase in moisture was 24 per cent in gunny sacks. In phase-I (days 6 to 10), free fatty acids ranged from 22.6 -31.0 (mg/100 g lipids) and phase-II (4 to 14 days), 27.0-32.3 (mg/100 g lipids). Respective peroxide values ranged from 18-27.3 (mg/100 g) in phase-I and 21.0-36.3 (mg/ 100 g) in phase –II versus 10.0-13.1 (mg/100 g) initially. The highest increase in free fatty acids, peroxide value and microbial count was seen in flour stored in gunny sacks.

Agarwal *et al.* (1990) studied the storability of jowar, bajra and their milled products (atta) in jute bags, polythene bags and tin containers under laboratory conditions for 7 months. It was inferred that development of rancidity was least in whole jowar and bajra stored in jute bags and maximum in polythene bags. Rancidity development was more in their respective flours as compared to whole grains. They reported that jowar and bajra could be stored in jute bags for about 7 months under normal conditions.

Shukla *et al.* (1986) analyzed 14 varieties of ragi for mineral contents. Both brown and white varieties were shown to be excellent source of Ca, Mg, S, P, Na, K and the micro nutrients Fe, Mn, Ca and Zn. Variety JNR100B contained these nutrients in appropriate quantity and was recommended for preparation of the low cost ready to eat nutritious food based on ragi.

Babu *et al.* (1987) analysed 6 hybrid varieties of ragi for chemical composition and protein content. The range of values was moisture 10.2-13.0, ash 2.5-2.9, protein 8.0-12.1, albumin 0.7-1.0, globulin 1.0-1.5, glutelin 4.3-4.6 and prolamine 1.9-3.4 per cent.

METHODOLOGY

Fineness modulus of flour:

The flour obtained at different plate speeds, plate clearances and feed rates was used to find out the fineness modulus of flour. The samples (250 g each) from ground flour were dried in an oven to a constant weight at 105^{0}C. The dried sample was placed in the top-most sieve and the whole set of 9 sieves was placed on a sieve shaking machine and shaken for 5 minutes. (The sieving machine consists of a set of 9 sieves and is manufactured by Amil sales and Agency Ltd., Bombay). The following were the sets of British standard sieves used for different fractions.

Sieve numbers	Width of opening (mm)
10	1.676
30	0.500
36	0.420
52	0.296
60	0.251
72	0.211
85	0.177
100	0.157
200	0.075
Pan	-

The fractions retained on each sieves were weighed and the fineness modulus was determined by adding the weight fraction retained above each sieve and dividing the sun by 100.

Nutritive value of flour:

The effect of milling on chemical composition of calcium, phosphorous and protein were analyzed by standard AOAC (Association of official Analytical Chemists) procedure.

Calcium:

Calcium is precipitated as calcium oxalate. The precipitate is dissolved in hot dilute sulphuric acid and titrated with standard potassium permanganate.

Phosphorus:

Phosphorous reacts with molybdic acid to form a phosphomolybdate complex. It was then reduced with aminoaphtholsulphonic acid in to complex molybdenum blue which is measured calorimetrically.

Protein:

The percentage crude protein is ascertained by multiplying the percentage of nitrogen other than ammoniacal nitrogen, by a factor. The quantity of ammoniacal nitrogen is separately determined and deducted from total nitrogen.

RESULTS AND DISCUSSION

The results obtained from the present study have been discussed in the following sub heads :

Effect of milling by manual operated mill (chakki) on fineness modulus of flour:

The fineness modulus of flour obtained by traditional milling was 2.52 and 2.61 for GPU-28 and L-15 ragi flours, respectively and these values were much higher compared to 2.04 and 2.06 in case of laboratory model mill.

Effect of milling by laboratory model mill of different operating conditions on fineness modulus of flour:

Effect of plate clearance on fineness modulus of flour:

Fineness modulus of ragi flour increased significantly with the increase of plate clearance. The increase in fineness modulus of flour form 2.044 to 3.436 was observed with the increase in plate clearance from 0.3 to 0.7 mm for GPU-28 ragi variety (Table 2). Increased fineness modulus from 2.056 to 3.456 recorded as the increased plate clearance from 0.3 to 0.7 mm for L-15 ragi variety (Table 6). The increase in fineness modulus was due to the fact that at higher plate clearance the flour obtained was coarser.

Table 1 : Effect of plate clearance and feed rate on fineness modulus of GPU-28 ragi flour at 450 rpm plate speed

Treatments	Fineness modulus
Plate clearances	
C_1 = 0.3 mm	2.360
C_2 = 0.5 mm	2.402
C_3 = 0.7 mm	3.446
F test	*
S.E. ±	0.0058
C.D. (P=0.05)	0.0175
Feed rate	
F_1 = 90 kg/h	2.512
F_2 = 100 kg/h	2.402
F_3 = 115 kg/h	2.708
F test	*
S.E. ±	0.0058
C.D. (P=0.05)	0.1075
Interaction	
C_1F_1	2.484
C_1F_2	2.360
C_1F_3	2.656
C_2F_1	2.512
C_2F_2	2.402
C_2F_3	2.708
C_3F_1	3.512
C_3F_2	3.446
C_3F_3	3.664
F test	*
S.E. ±	0.0101
C.D. (P=0.05)	0.0303

Note: C_1, C_2 and C_3 denote plate clearances.
F_1, F_2 and F_3 denote feed rates
*denotes significant

Table 2 : Effect of plate clearance and feed rate on fineness modulus of GPU-28 ragi flour at 600rpm plate speed

Treatments	Fineness modulus
Plate clearances	
C_1 = 0.3 mm	2.044
C_2 = 0.5 mm	2.384
C_3 = 0.7 mm	3.436
F test	*
S.E. ±	0.0008
C.D. (P=0.05)	0.0025
Feed rate	
F_1 = 90 kg/h	2.184
F_2 = 100 kg/h	2.044
F_3 = 115 kg/h	2.224
F test	*
S.E. ±	0.0008
C.D. (P=0.05)	0.0025
Interaction	
C_1F_1	2.184
C_1F_2	2.044
C_1F_3	2.224
C_2F_1	2.476
C_2F_2	2.384
C_2F_3	2.620
C_3F_1	3.464
C_3F_2	3.436
C_3F_3	3.648
F test	*
S.E. ±	0.0014
C.D. (P=0.05)	0.0043

Note: C_1, C_2 and C_3 denote plate clearances.
F_1, F_2 and F_3 denote feed rates
*denotes significant

Effect of feed rate on fineness modulus of flour:

Feed rate also had direct influence on fineness modulus. The fineness modulus of flour decreased initially as the feed rate increased upto an optimum value, later on it increased as the feed rate increased further. Increased feed rate from 90 to 100 kg/h, decreased the fineness modulus from 2.184 to 2.044 in GPU-28 ragi flour (Table 2). But, further increase in feed rate from 100 to 115 kg/h increased the fineness modulus from 2.044 to 2.224. The similar effect was also observed in case of L-15 variety (Table 6). The high value of fineness modulus at higher feed rate may be attributed to the fact that the higher shear and compressive forces which reduced the residence time resulted in coarser grinding. Similar effect at lesser feed rate may be due to inadequate grain availability between the plates hence the coarser grinding.

Effect of plate speed on fineness modulus of flour:

The uniformity of the ground flour was greatly affected by the variation in the plate speed. As the plate speed increased, the fineness modulus decreased initially and further increase in plate speed resulted in increased fineness modulus. Decreased fineness modulus from 2.360 to 2.044 was recorded as the plate speed increased

Table 3 : Effect of plate clearance and feed rate on fineness modulus of GPU-28 ragi flour at 700 rpm plate speed

Treatments	Fineness modulus
Plate clearances	
C_1 = 0.3 mm	2.164
C_2 = 0.5 mm	2.388
C_3 = 0.7 mm	3.344
F test	*
S.E. $\pm$	0.6040
C.D. (P=0.05)	0.1919
Feed rate	
F_1 = 90 kg/h	2.224
F_2 = 100 kg/h	2.164
F_3 = 115 kg/h	2.388
F test	*
S.E. $\pm$	0.0640
C.D. (P=0.05)	0.1919
Interaction	
C_1F_1	2.224
C_1F_2	2.164
C_1F_3	2.388
C_2F_1	2.532
C_2F_2	2.388
C_2F_3	2.672
C_3F_1	3.520
C_3F_2	3.344
C_3F_3	3.624
F test	*
S.E. $\pm$	0.1109
C.D. (P=0.05)	0.3324

Note: C_1, C_2 and C_3 denote plate clearances.
F_1, F_2 and F_3 denote feed rates
*denotes significant

Table 4 : Effect of plate speed, plate clearance and feed rate on fineness modulus of flour Ragi: variety GPU-28

Treatments	Fineness modulus
$S_1C_1F_1$	2.484
$S_1C_1F_2$	2.360
$S_1C_1F_3$	2.656
$S_1C_2F_1$	2.512
$S_1C_2F_2$	2.402
$S_1C_2F_3$	2.708
$S_1C_3F_1$	3.512
$S_1C_3F_2$	3.446
$S_1C_3F_3$	3.664
$S_2C_1F_1$	2.184
$S_2C_1F_2$	2.044
$S_2C_1F_3$	2.22
$S_2C_2F_1$	2.476
$S_2C_2F_2$	2.384
$S_2C_2F_3$	2.620
$S_2C_3F_1$	3.464
$S_2C_3F_2$	3.436
$S_2C_3F_3$	3.648
$S_3C_1F_1$	2.224
$S_3C_1F_2$	2.164
$S_3C_1F_3$	2.388
$S_3C_2F_1$	2.532
$S_3C_2F_2$	2.388
$S_3C_2F_3$	2.672
$S_3C_3F_1$	3.520
$S_3C_3F_2$	3.344
$S_3C_3F_3$	3.624
F test	*
S.E.$\pm$	0.4926 – 01
C.D. (P=0.05)	0.1365+00

Note: C_1, C_2 and C_3 denote 0.3, 0.5 and 0.7 mm plate clearance
F_1, F_2 and F_3 denote 90, 100 and 115 kg/h feed rates
S_1, S_2 and S_3 denote 450, 600 and 700 rpm plate speeds
*denotes significant

from 450 to 600 rpm. Later, it increased from 2.044 to 2.164 as the plate speed further increased from 600 to 700 rpm for GPU-28 ragi flour (Table 1, 2 and 3). Similar results were also obtained for L-15 ragi flour (Table 5, 6, 7). These results are inconformity with the studies made by Ernesto *et al.* (1990) on rice flour.

The decrease in fineness modulus at optimum plate speed might be due to the fact that there was a co-ordination between feed rate and plate speed to maintain optimum milling forces. These forces are just sufficient to produce greater percentage of finer fractions. The higher values of fineness modulus at higher plate speed might be due to the increased centrifugal force which reduces the residence time.

Interaction of plate clearance, feed rate and plate speed on fineness modulus of flour:

The three way interaction showed significant difference among different treatments. Fineness modulus was significantly superior (2.044) for the combination

Table 5 : Effect of plate clearance and feed rate on fineness modulus of L-15 ragi flour at 450rpm plate speed

Treatments	Fineness modulus
Plate clearances	
C_1 = 0.3 mm	2.340
C_2 = 0.5 mm	2.376
C_3 = 0.7 mm	3.456
F test	*
S.E. ±	0.0007
C.D. (P=0.05)	0.0022
Feed rate	
F_1 = 90 kg/h	2.556
F_2 = 100 kg/h	2.376
F_3 = 115 kg/h	2.712
F test	*
S.E. ±	0.0007
C.D. (P=0.05)	0.0022
Interaction	
C_1F_1	2.488
C_1F_2	2.340
C_1F_3	2.684
C_2F_1	2.556
C_2F_2	2.376
C_2F_3	2.712
C_3F_1	3.480
C_3F_2	3.456
C_3F_3	3.664
F test	*
S.E. ±	0.0012
C.D. (P=0.05)	0.0037

Note: C_1, C_2 and C_3 denote plate clearances.
F_1, F_2 and F_3 denote feed rates
*denotes significant

Table 6 : Effect of plate clearance and feed rate on fineness modulus of L-15 ragi flour at 600 rpm plate speed

Treatments	Fineness modulus
Plate clearances	
C_1 = 0.3 mm	2.056
C_2 = 0.5 mm	2.388
C_3 = 0.7 mm	3.456
F test	*
S.E. ±	0.0003
C.D. (P=0.05)	0.0009
Feed rate	
F_1 = 90 kg/h	2.208
F_2 = 100 kg/h	2.056
F_3 = 115 kg/h	2.288
F test	*
S.E. ±	0.0003
C.D. (P=0.05)	0.0009
Interaction	
C_1F_1	2.208
C_1F_2	2.056
C_1F_3	2.288
C_2F_1	2.476
C_2F_2	2.388
C_2F_3	2.672
C_3F_1	3.512
C_3F_2	3.456
C_3F_3	3.752
F test	*
S.E. ±	0.0005
C.D. (P=0.05)	0.0025

Note: C_1, C_2 and C_3 denote plate clearances.
F_1, F_2 and F_3 denote feed rates
*denotes significant

treatment of 600 rpm plate speed, 0.3 clearance and 100 kg/h feed rate followed by that of 600 rpm plate speed, 0.5 mm plate clearance and 100 kg/h feed rate (2.384) for GPU-28 ragi variety (Table 4).

Effect of milling on nutritive value of ragi flour:

Chemical composition of the flour obtained from manually operated mill (chakki) showed significantly higher nutritive value. The loss of nutrients was minimum in flour milled by traditional method as compared to milling by laboratory model mill. Calcium, phosphorus and protein values were 0.61, 0.30 and 11.51 per cent, respectively for the flour obtained from traditional mill (Chakki) as compared to 0.49, 0.23 and 11.38 per cent for the flour obtained from laboratory model mill (Table 9).

Plate clearance had negative bearing on the nutritive value of flour. The GPU-28 ragi flour was analyzed for calcium, phosphorus and nitrogen. The results showed that as the plate clearance increased, the deterioration of nutrients also increased. The calcium value recorded was 0.33 per cent at 0.3mm clearance as compared to 0.53 per cent at 0.7mm plate clearance. Phosphorus and protein values were 0.22 and 10.35 per cent at 0.3mm clearance in contrast to 0.25 and 11.45 per cent at 0.7 mm clearance (Table 9).

Reduction in nutrient value at lower plate clearance

Table 7 : Effect of plate clearance and feed rate on fineness modulus of L-15 ragi flour at 700 rpm plate speed

Treatments	Fineness modulus
Plate clearances	
C_1 = 0.3 mm	2.164
C_2 = 0.5 mm	2.412
C_3 = 0.7 mm	3.344
F test	*
S.E. ±	0.0009
C.D. (P=0.05)	0.0026
Feed rate	
F_1 = 90 kg/h	2.572
F_2 = 100 kg/h	2.412
F_3 = 115 kg/h	2.680
F test	*
S.E. ±	0.0009
C.D. (P=0.05)	0.0026
Interaction	
C_1F_1	2.224
C_1F_2	2.164
C_1F_3	2.388
C_2F_1	2.572
C_2F_2	2.412
C_2F_3	2.680
C_3F_1	3.520
C_3F_2	3.344
C_3F_3	3.624
F test	*
S.E. ±	0.0015
C.D. (P=0.05)	0.0044

Note: C_1, C_2 and C_3 denote plate clearances.
F_1, F_2 and F_3 denote feed rates
*denotes significant

Table 8 : Effect of plate speed, plate clearance and feed rate on fineness modulus of flour Ragi: variety L-15

Treatments	Fineness modulus
$S_1C_1F_1$	2.488
$S_1C_1F_2$	2.340
$S_1C_1F_3$	2.684
$S_1C_2F_1$	2.556
$S_1C_2F_2$	2.376
$S_1C_2F_3$	2.712
$S_1C_3F_1$	3.480
$S_1C_3F_2$	3.456
$S_1C_3F_3$	3.664
$S_2C_1F_1$	2.208
$S_2C_1F_2$	2.056
$S_2C_1F_3$	2.288
$S_2C_2F_1$	2.476
$S_2C_2F_2$	2.388
$S_2C_2F_3$	2.672
$S_2C_3F_1$	3.512
$S_2C_3F_2$	3.456
$S_2C_3F_3$	3.752
$S_3C_1F_1$	2.224
$S_3C_1F_2$	2.164
$S_3C_1F_3$	2.388
$S_3C_2F_1$	2.572
$S_3C_2F_2$	2.412
$S_3C_2F_3$	2.680
$S_3C_3F_1$	3.520
$S_3C_3F_2$	3.344
$S_3C_3F_3$	3.624
F test	*
S.E.±	0.4927 – 01
C.D. (P=0.05)	0.1365+00

Note: C_1, C_2 and C_3 denote 0.3, 0.5 and 0.7 mm plate clearance
F_1, F_2 and F_3 denote 90, 100 and 115 kg/h feed rates
S_1, S_2 and S_3 denote 450, 600 and 700 rpm plate speeds
*denotes significant

might be due to the heat generated by rubbing action of closely revolving plates. This might converts the calcium in to other form of calcium compounds.

Plate speed also showed significant effect on nutritive value of flour. The increased speed reduced the nutrient value. As the speed increased from 450 to 700 rpm the corresponding values of calcium, phosphorus and protein reduced from 0.49 to 0.33, 0.25 to 0.16 and 11.62 to 10.29 per cent, respectively. Reduced nutrient values of flour with the increased plate speed might be due to higher shear and compressive forces (Table 9).

Table 9 : Effect of plate clearance and plate speed on nutritive value of ragi (variety GPU-28)

Treatments	Calcium (%)	Phosphorus (%)	Protein (%)
$S_2C_1F_2$	0.330	0.220	10.350
$S_2C_2F_2$	0.490	0.230	11.380
$S_3C_2F_2$	0.530	0.250	11.450
$S_1C_2F_2$	0.495	0.250	11.620
$S_2C_2F_2$	0.490	0.230	11.450
$S_3C_2F_2$	0.330	0.160	10.290

Note: C_1, C_2 and C_3 denote 0.3, 0.5 and 0.7 mm plate clearance
F_2 and denote 100 kg/h feed rate
S_1, S_2 and S_3 denote 450, 600 and 700 rpm plate speeds

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