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MILLING STUDIES OF PULSES USING DIFFERENT PRE-MILLING TREATMENT OF PIGEON PEA (*CAJANUS CAJAN*)

MEDHA VYAS
ASST. TECHNOLOGY MANAGER
AGRICULTURE TECHNOLOGY MANAGEMENT AGENCY (ATMA)
DAMOH

PRIYANKA BHADOURIYA
ASST. TECHNOLOGY MANAGER
AGRICULTURE TECHNOLOGY MANAGEMENT AGENCY (ATMA)
SAGAR

ABSTRACT
Pigeonpea (Cajanus cajan (L.) Millspaugh) popularly called as tur or arhar, is second most important pulse crop of India due to its several unique characteristics. It is the most versatile food legume with diversified uses as food, feed, fodder as well as fuel. It has been recognized as a valuable source of protein particularly in the developing countries like India where majority of the population depends on the low-priced vegetarian foods for meeting its dietary their reliance on vegetarian diets besides limited buying capacity of more than 27% people living below the poverty line. This research relates to "Performance Evaluation Of CFTRI Dal Mill For Pigeon Pea" and aims to increase the recovery of dal. For experimentation, Arhar of variety T-21 was selected, as it is considered to be the one of the most populer variety in Madhya Pradesh. Examination of physical properties like moisture content, angle of repose, true density and coefficient of static friction of Arhar was done after treating it with moisture, NaCl & $NaHCO_3$ followed by sundrying and grinding in the CFTRI Dal mill. Experiments show that grains soaked for one hour gave higher dal recoveries then 30 min and 2 hours soaked grains. In general, there was increase in dal recovery with the increase in moisture content but it was observed that it falls beyond 10% moisture content. NaCl treatment of grain of 6% concentration gave highest dal recovery when the grains were milled at 10% moistures content. Also, the generation of powder and broken was minimum at 6% NaHCo3 and 10% moisture content of grain. This research led to the result that at 6% $NaHCO_3$ concentration & 10.5% moisture content the recovery of dal is highest.

KEYWORDS
pigeonpea, CFTRI Dal mill, treatments, milling, dal recovery.

INTRODUCTION
Pulses occupy a prominent place in the agricultural economy and play a remarkable role in agricultural productivity. Pigeonpea (Cajanus cajan (L.) Millspaugh) popularly called as tur or arhar, is second most important pulse crop of India due to its several unique characteristics. Pigeon pea is an important pulse crop of the world belonging to the natural order leguminoceae. Pigeonpea is grown as a sole as well as intercrop. Pigeonpea has as long history of research as any other pulse crops in the country. It started as early as in 1905 when imperial Agricultural Research Institute (IARI), Pusa made a modest beginning by taking up research work on the crop. Similar research programmes particularly for purification of the existing heterogeneous land races were initiated Bombay (Maharashtra and Gujarat) and Central India (Madhya Pradesh). However, systematic and concerted research on Pigeonpea started with the establishment of the All India Coordinated Pulses Improvement Project (AICPIP) in 1967. Realizing the importance of the crop, the AICPIP was trifurcated to work exclusively on Pigeonpea with seven research centers in the country during the VIII Plan. The All India Coordinated Research Project on Pigeonpea has stated functioning in 1995 and presently has a network of 22 centers across the country. These research centers have been playing a crucial role in pigeon pea improvement not only as testing centers but also as major contributors of technologies for testing across the county. With initial success in exploiting genic male sterility based hybrid at ICRISAT, the country took up a mission mode project on hybrids in major crops including pigeon during 1989, this project took off at ten centers including, IIPR, IARI, PAU, GAU, PKV, TNAU, RAU, UAS Bangalore, HAU and NDAU&T with major emphasis on development of genic male sterility based hybrids, identification and diversification of cytoplasm male sterility system and its fertility restorer lines, and productive hybrid combinations.

REVIEW OF LITERATURE
This chapter deals with review of research work so for carried out in the pulses milling field. The research so carried in pulses milling is being put under major heads namely: - drying of pulses, loosening of husk, milling and separation.

- **LOOSENING OF HUSK**

Different treatments have been suggested for the preconditioning of pulses before milling to loosen the adhesive bond between the kernel and the husk.

The CFTRI technique (Kurien et al., 1968) eliminated oil application completely while loosening of husk was effected by successive heating and cooling of pulses. The pulses grains were subjected to heated air (120-160^{0}C) for a specific duration of time. The grain temperature reached between (65-75^{0}C). Later the grains were cooled by forcing ambient air through the grains.

The successive heating and cooling was reported to be effective in destroying the adhesive bond between the husk and the cotyledons. More than 95 percent of Arhar was dehusked in one pass through dehusking roller machine.

Krishnamurthy et al., (1972) reported that 'sirka' can be used in place of oil in Arhar milling. It was observed that the recovery in this process was more or less same as in case of oil application.

Patil (1977) compared dry and wet milling of Arhar by laboratory emery roller (Satake rice polisher) for milling effectiveness, cooking quality and swelling index. Different premilling treatments were attempted such as:

1. Soaking of 200g sample (10.86% db) in 600ml preheated water at room temperature, 60 ^{0}C, 75^{0}C and 90^{0}C for the durations of 24 -25 hours steeping at room temperature and 0.25-4 hours for hot water steeping followed by sun drying (2-5 days) up to 14% db.
2. Dry conditioning at 80^{0}C, 100^{0}C and 120^{0}C for 3.45, 7.25 and 20.50 hours.
3. Water steeping at 60^{0}C, 75^{0}C and 80^{0}C for 0.5 and 1 hour followed by roasting for 5 minutes and sun drying for 2 days.
4. Soaking in NaOH solution (3%) for 0.5 to 1 hour at room temperature.

The highest milling efficiency (85%) was obtained by steeping at 80^{0}C and roasting. However, wet methods of treatments brought improvement in milling quality, the cooking quality was lowered.

The loosening of Arhar husk by sand roasting was tried by Karsolia (1978). The roasting was carried out at temperature of 75^{0}C to 125^{0}C for 1 to 10 minutes. The highest milling efficiency (95%) was obtained by roasting at 125^{0}C for 5 minutes. It was reported that cooking quality of Dal was similar to commercially available dal, maximum swelling index was 3.12 and the water uptake was maximum after 50 minutes of cooking time.

In Coimbatore, Arhar was subjected to different hydrothermal treatment combinations before milling (Annual Report, Coimbatore Centre 1979). It was observed that 2 hours soaking followed by 1 hour sun drying gave the best milling results.
Kurien (1980) found that the gumminess of pulses, which holds the husk, is due to caloctomanus disaccharide, glucoronaic acid and glycoprotein.
Reddy (1981) after trials with different combinations of treatments observed that the pulses at 10.5 percent moisture, dry basis gave highest milling efficiency (67.23%) when treated with 1 N Sodium Bicarbonate solution and milled in a concave cylinder dehusker having 6 mm and 4 mm as entrance and exit clearance respectively with a cylinder speed of 400 rpm.
Singh and Narain (1984) tried several chemical treatments and found that Arhar sample soaked in 6 percent Sodium Bicarbonate solution for 1 hour and subsequently dried to a moisture content of 10 percent gave maximum Dal recovery with minimum brokens and powder, maximum dehusking was obtained at moisture 8% db.
Khan and Phirke (1990) reported that with application of medicinal oils such as neem and karanj oil, the pulses can be safely stored for a year or more while if edible oils such as groundnut or safflower were applied, a safe storage life up to 150 days could be achieved.

- **MILLING OF PULSES**

A few attempts have been made to improve the milling technology and the machines used for milling. It has been compiled in following text.
Singh (1976) reported the use of rice polisher (satake make) for shelling and splitting of Arhar.
Sagar and Singh (1978) developed a new concave cylinder dehuller for dehusking of pulses. It was reported to have cylinder of 38cm length with knurled surface and the concave made from 16 gauges M.S. Sheet. It was found to give satisfactory dehulling efficiency.
Rao (1980) studied the force deformation characteristics of Arhar (T-21) and found the force required for splitting. It was observed that the ratio between force for split and force for rupture increased with increase in moisture of the grains.
Siripurapu et al. (1980) reported milling efficiency of domestic flour mill increased with increase in feed rate when clearance between two stones is more than the maximum size of pulses. Maximum efficiency (73%) was reported for arhar in one pass at the feed rate of 29 kg/h at 6.05 m clearance.
JBCRI (1982) modified the traditional domestic flour mill and used it for Dal milling successfully.
Teckchandani et al. (1982) tested different machines viz, stone roller (15" ø X 35", 400 rpm, 7.5 hp), URD Sheller (30"ø X4" thick, 900 rpm) and burr mill (16" ø , rpm, 10 hp) for bengal gram (7G-62, husk content 13.2%). The pulses were steeped in water for 1 minute, dried in sun for a day and milled. Highest yield was obtained in burr mill in one pas which the URD Sheller had the lesser broken percentage (6%) than that of burr mill (16%).
Kumar et al. (1983) reported Dal yield of 75 percent by milling Arhar in concentric double cylinder machine for dehusking and splitting of Soybean. The cylinder concave dehuller with 6 mm entrance and mm exit clearance running at a speed of 300-400 rpm gave the best results in terms of dehulling efficiency (83.9%) and minimum broken percentage (less than 3%) at a grain moisture between 12-15 percent.
Singh D. and Sokhanganj (1984) reported milling of Arhar by concave cylinder dehuller and also suggested treatment to achieve best milling results. He suggested the treatments of acetic acid (20-100% pure solution,) Sodium Bicarbonate (0.2 to 1 N) and mustard oil (0.2 to 1% of the rain mass.) The treated samples were then stored for 24 hours and then milled at moisture content range between 6.7-16.4% db. The best results in terms of milling efficiency were obtained for concave clearance 5 and 1. 75 mm at inlet and outlet respectively, at speed of 300-500 rpm and at grain moisture content of 8.9 percent db.
Sahay et al. (187) observed that optimum carborandum number of dehusking roll for dehusking Arhar, Moong and Urd was 30, 40, and 24 respectively.

- **SEPARATION**

Teckchandani (1986, 1988, 1990) developed on Arhar – GOTA separator based on the principle that GOTA surface was covered with natural gum layer while the whole arhar grain did not have any such gum layer. Experiments revealed that slightly moistened GOTA stuck to a textured cloth while whole Arhar grain did not. This principle combined with the action of centrifugal and gravity force of moving flat belt was employed to separate out GOTA from Arhar – GOTA mixture. Removal of GOTA after each stage of dehusking increased over all Dal recovery by 3- 3.5 percent.
Kurien (1987) used differences in bouncing property of Arhar and gota for separation of gota from Arhar – GOTA mixture.
Teckchandani (1988) pointed that during milling of Arhar, splits are separated out at intermediate stages due to difference in physical properties. However, GOTA (unsplit dehusked grains) is not separated out from whole Arhar –GOTA mixture due to similar physical properties. Due to this GOTA along with Arhar is repeatedly passed through dehusking roller till 95 percent of Arhar is dehusked. The undesirable dehusking passes remove a portion of kernel mass of GOTA and thus increase the overall milling losses.

DEVELOPMENT OF MINI DAL MILLS

Singh et al. (1984) developed an industrial scale Dal mill with a rated capacity of 400 kg/h.
Kurien (1987) developed a simple hand operated pulses dehusking machine suitable for Arhar and bengal gram with a capacity of 35 and 65 kg/h for first and second pass of milling respectively.
Sahay et al. (1988) reported to have developed a mini abrasive roller machine for milling pulses at a capacity of 100 kg/h.
Phirke (1990) developed a mini Dal mill operated by 1 hp electric motor. It was reported to suitable for villages.

- **ORIGIN, HISTORY, BOTANICAL DESCRIPTION AND PRODUCTION**

India ranks first in both area and production of all important pulses grown viz. pigeon pea, green gram, black gram etc. Pigeon pea (Cajanus cajan (L) Mills. synonyms: Cajanus indicus Spreng) also known as arhar, tur, redgram, congopea etc. is one of the most important pulse crops cultivated in India. Its grains are highly nutritious and rich in protein (21.7%), Carbohydrates, Fiber and minerals.
Husk contain in pigeon pea 13-15%. The Botanical name of Arhar is cajanus cajan. Its chemical composition and structure are: -
Fat - 1.7 %
Mineral -3.5%
Moisture -10.35 %
Protein - 24.19%
Ether extract -1.89%
Ash - 3.55%
Crude Fiber - 1.01%
Carbohydrate - 59.21%
Alam et. all (1975) surveyed sample Dal mill in Jabalpur, Sagar, and Katni studying the processes and equipment use and level of Dal recovery in the existing mills. They found that recovery of Dal in case of Arhar (red gram), Urid and Moong (green gram) and Batri (pigeon pea) is comparatively low and it should be possible to improve recovery by 5-10% through improvement in dehusking device and or process. They also observed that the Dal mills in the area operate very dusty and for want of suitable dryer these mills are virtually closed in the rainy season and bad weather.

IMPORTANCE OF THE STUDY

Pigeonpea, is the most versatile food legume with diversified uses as food, feed, fodder and fuel. It has been recognized as valuable source of protein particularly in the developing countries where majority of the population depends on the low-priced vegetarian foods for meeting its dietary their reliance on vegetarian diets besides limited buying capacity of more than 27% people living below the poverty line. Like any other pulses, supplementation of Pigeonpea with cereal based diets is considered one of the possible solutions to alleviate protein energy malnutrition. Pulses are often quoted as cheep and rich protein source for predominately vegetarian and a poor man where about 15-30% of daily proteins are supplied from edible legumes or pulses. In recent years the demand of pulses has increased due to increase in population.
India accounts for 78% of the global output with current production of 2.21 million tones from 3.38 million ha recording average yield of 653 kg/ha. Pigeonpea production has gone up in the country from 1.98 million tones during the triennium of 1980-82 to 2.40 million tones in 2000-02 because of area expansion from

2.86 to 3.46 million ha during the period. The country has recorded positive growth of 1.72% annually in Pigeonpea production between 1981 and 2001. if it was the area expansion between 1981 and 1991 as the major factor for positive growth, then yield advance was turned out to be the main force during the second decade (1991-2001).

During 2003-04, Pigeonpea was grown on about 3.53 million ha area with 2.43 million tones of production, which represent 14.44 and 15.95% of the national pulse acreage and production, respectively. Pigeonpea is the second most important pulse crop in the country with production base concentrating in Maharashtra, Uttar Pradesh, Karnataka, Gujarat, Madhya Pradesh and Andhra Pradesh. Together these states contribute 83.3% of the production from 86% of the area. Maharastra alone accounts for 35.5% of the national Pigeonpea production from an area of 31.4%.

The above facts clarify the importance of Pigeonpea in Indian economy and society. This study will help increase its productivity of Pigeonpea which will positively affect the greater causes.

OBJECTIVES

1. Performance & Optimization of pre conditioning treatment and operational parameters for maximum recovery.
2. To study the effect of pre conditioning treatment on dehusking, gota formation, broken percentage and percentage mealy waste of pigeon pea.

HYPOTHESIS

Alam et. all (1975**)** surveyed sample Dal mill in Jabalpur, Sagar, and Katni studying the processes and equipment use and level of Dal recovery in the existing mills. They found that recovery of Dal in case of Arhar (red gram) Urid and Moong (green gram) and Batri (pigeon pea) is comparatively low and it should be possible to improve recovery by 5-10% through improvement in dehusking device and or process. They also observed that the Dal mills in the area operate very dusty and for want of suitable dryer these mills are virtually closed in the rainy season and bad weather.

To get the exact picture of how exactly a dal is dehusked and split into two and which of the operations give better dal milling efficiency and which one's saves loses, thus domestic dal milling methods adopted by various regions where studied. The steps in which dal milling is performed by various region of India like Village– Sahajpur, Tahsil- Patan, District- Jabalpur:

- Arhar
- Washing of Arhar
- Sundrying for 1 day
- Oil mixing @ 5 gm per kg.
- Grinding in domestic stone grinder
- Water soaking
- husk and
- Sun drying
- Haldi in dal
- Separation of Husk and Milled Dal
- Grinding
- Haldi + oil mixing in dal

RESEARCH METHODOLOGY

This project, as earlier explained relates to "Performance Evaluation Of CFTRI Dal Mill For Pigeon Pea" and aims to increse the recovery of dal.

For experimentation, Arhar of variety T-21 was selected, as it is considered to be the one of the most populer variety in (M.P.).

After going through the review of literature related to research done on this aspect of pulses and Arhar, following treatments were selected.

PRETREATMENT

Arhar pulse was cleaned and pased through CFTRI Dal Mill and grader sieve in Laboratory Sieve Cleaner –cum – Grader to get uniform size arhar grains. The treated grains were milled at 6%,8%,10% and 12% moisture content. In general there was increase in dal recovery with the increase in moisture content. However, it falls beyond 10% moisture content. The highest amount of dal was obtained at 10% moisture content the production of powder and brokens were also increased with the increase in concentration. These observations are true in both the case of chemicals used i.e. NaCl&$NaHCO_3$ for treating the grain respectively. After draining and sun drying for whole day, moisture content was determined with Universal Moisture Meter. Sample of 1.5 kg weight each were subjected to milling. The milling was done in CFTRI Dal mill.

The milled sample was collected in one lot and its different ingredients were separated. The ingredients were – Husk, Dal, GOTA mixture and broken kernels.

All these ingredients were weighted accurately with the help of electronic balance and put in the tabular form. Each experiment was replicated 5 times.

These control pretreatments helped to compare milling effectiveness of treatments given to Arhar pulse.

DETERMINATION OF PHYSICAL PROPERTIES

- **MOISTURE CONTENT**

Moisture content of pigeon pea was determined by hot air oven/vacuum oven method by following the method as suggested by Hall (1971). Weighed sample (50 g approx) was placed in the hot air oven preheated to the desirable temperature. The samples were kept either for 100 ± 2^0 C for 18 hours in hot air oven or for 6 hrs. in vacuum oven. The bone dry samples thereafter taken out from the oven and were placed in desiccators to ambient temperature and then the difference in weight was noted. The moisture content thus determined was expressed in terms of wet basis or dry basis.

ADDITION OF MOISTURE

The moisture content of pigeon pea was measured after getting the moisture content of different samples additional water required for desired moisture content levels in the samples i.e. 6%, 8% and 10% (w.b.) was calculated. Then the calculated amount of water plus and additional amount of 10% of calculated water was added to supplement the evaporation losses during mixing and conditioning. Then tempering of samples was done by keeping the moisture added sample for 24 hrs. at room temperature so that to get uniform moisture content throughout the samples.

For adding the moisture up to desired level calculate initial moisture content and calculate the water required for desired level moisture content.

$$W_w = W_d \left(\frac{(M_2 - M_1)}{(1 - M_1)(1 - M_2)} \right)$$

Where

W_w = weight of water to be added

W_d = Bone dry wt. of raw material

M_1 = Initial Moisture content of material (w.b. in decimal)

M_2 = Desired Moisture content of material (w.b. in decimal)

- **TRUE DENSITY**

The true density values of pigeon pea at various moisture contents were determined by liquid displacement method using kerosene a liquid of low specific gravity. 10 gram sample was introduced in the measuring cylinder and the difference in level of liquid was noted. Three replications were taken for each measurement and the mean was reported as:

Mass of sample
True density = ------------------------
True volume of sample

- **Angle of Repose**

The angle of repose is the angle between the base and the slope of the cone formed vertical fall of the granular material on horizontal plane.

Angle of repose was calculated by making the regular heap by dropping the pigeon pea through funnel over smooth surface. The height and diameter of the heap were measured by measuring tape. Angle of repose was calculated by using following relation:

Angle of repose (degree) = $\tan^{-1}$ (height/radius)

- **Coefficient of static friction**

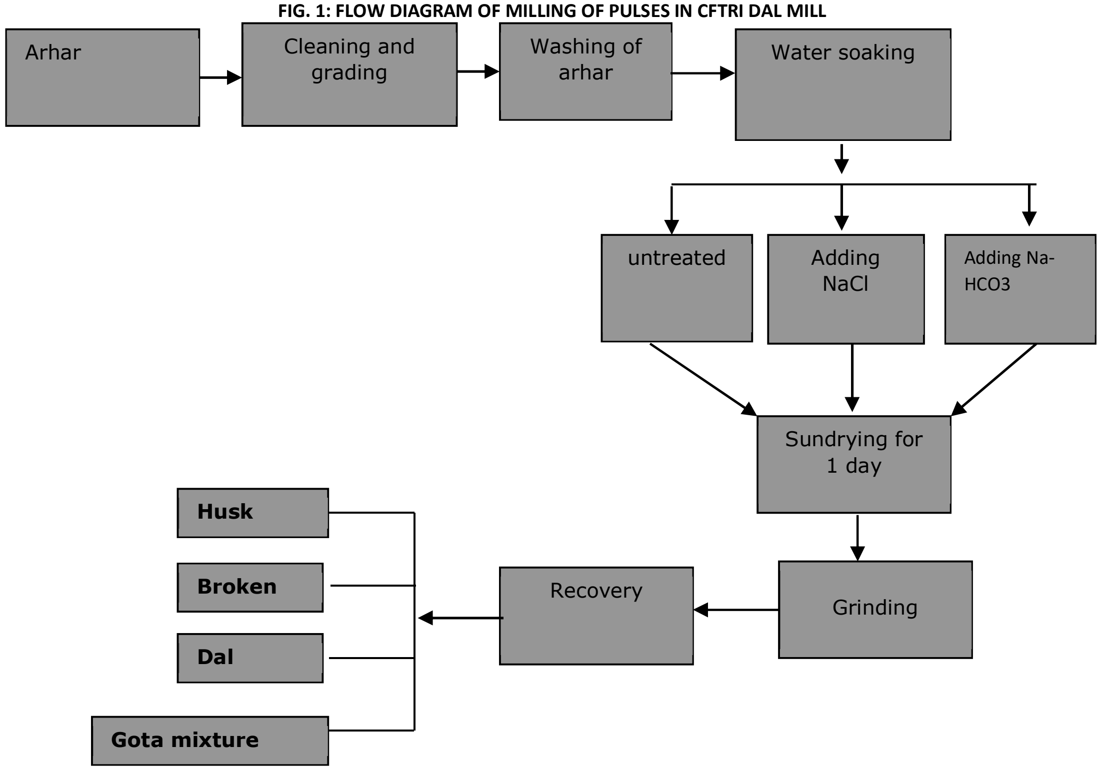
Coefficient of friction was computed by using inclined plane. Glass Wooden and metal sheet were placed one by one on movable plane. Pigeon pea was then placed over the surface. The movable plane was then gradually lifted to a position where by the bran had just started sliding down to the plane. The plane was clamped at this position and angle of friction was measured. The same procedure was repeated thrice for the various moisture contents adjusted. The coefficient of friction was determined by the following relation (Sahay and Singh, 2003):

The coefficient of friction $\mu = \tan \varnothing$

Where, μ = Coefficient of static friction.

$\varnothing$ = angle of static friction

FIG. 1: FLOW DIAGRAM OF MILLING OF PULSES IN CFTRI DAL MILL



TO CALCULATE THE EFFECTIVENESS OF MILLING

With above facts, following indices were developed and multiplied to each other to get the overall milling index. Here the difficulty was felt while differentiating between the GOTA and dal content of milled sample to obtain the meaningful milling index. The value of dal was reduced with respect to GOTA dal as per the comparative difference in market price of GOTA dal (Grade –I) and Dal (Grade –II dal.)

- **Formula for Milling Efficiency**

1. $\eta = (1-M_{uh}./M_{t})(1-M_b/M_t)xHIx100$
2. $HI = H_a/H_t$

Where

η = milling efficiency
M_{uh} = mass of unhulled grains
M_t = mass of grains fed to the system
M_b = mass of broken
H_a = actual mass of husk removed during milling
H_t = theoretical husk content of the grain

- **Calculation for finding efficiency of milling:**

1. GOTA index $\eta_G = G/(P- H)$
2. Dal index $\eta_D = D/ (P- H)$
3. Dal with husk index $\eta_{DH} = \{P-D_H\}/P$
4. Broken index $\eta_B = \{(P-H_1)–B\}/(P-H_1)$
5. (GOTA + Dal) index $\eta_{GD} = (G+xD) /(P-H), X = C_D/C_G$

Where:

G = weight of GOTA, g
D = weight of dal, g

P = weight of whole pulse, g
H = weight of husk,g
D_H = weight of dal with husk, g
B =weight of (brokens + powder), g
C_D = cost of dal = Rs 3800/q.
C_G = cost of GOTA = Rs. 4000/q.

- **Calculation of Husk (H) & brokens (B)**

1. $H = H_1 (G+D)/GD$
2. $B = P – (G + D +D_H + P_1 + H$

Where
H_1 = 15% of P for arhar variety: T: 21
= 0.15P
Then GD =85% of P
=0.85 P
P_1 = Whole Pulse in dehusked sample

- **Calculation of overall Milling Index**

$\eta_o = \eta_{GD} X \eta_{DH} X \eta_B$
Where:
η_o = Overall milling efficiency

RESULTS & DISCUSSION

The chemically treated grains were milled separately and percentage of fractions tabulated. Table.1 and Table 2 shows the percentage obtained when treated with sodium chloride and sodium Bicarbonate respectively. All the tests were conducted on one hour soaked grains in respective chemicals. Experiments show that grains soaked for one hour gave higher dhal recoveries then 30 min and 2 hours soaked grains. Initial imbibition's period of one hour was sufficient to increase the moisture content of the grain up to 29%-30% depending up on the ambient temperature. However, soaking beyond 30 minutes' duration, leaching of chemical nutrients occur which changes the Colour of the substrate. The increase in moisture consent swells the content of the grain. The rate of swelling is different for different constituent of the grain. The subsequent drying of the grain thereby looses the hand strength between the hook and kernel. This effect has clearly been shown the in figures 1 to 2. The recovery of dhal powder and brokens were plotted against concentration of the chemical used for treating the grain. The treated grains were milled at 6%,8%,10% and 12% moisture content. In general, was increase in dhal recovery with the increase in moisture content. However, it falls beyond 10% moisture content. The highest amount of dhal was obtained at 10% moisture content the production of powder and brokens were also found increasing with the increase in concentration. These observations ate true in both the case of chemicals used treating the grain in Nacl and NaHOo3.

The experiments conducted to determine the hardness of grain, show that the it has highest value of hardness (18 kg-force) at 8% moisture content. These values are much lower at 6% and 10% moisture contents, that is 13.6 kg force and 8.5kg force respectively. This is reason for higher dhal recovery at 10.0% moisture content.The fig.3.9 cibfurn tge statuette.The recoveries of fhal ,powder, brokens and husked kernel coincided abd tabulated in table 3.3 NaCl treatment of grain of 6% concentration gave highest dhal recovery when the grains were milled at 10% moistures content. However, the generation of powder and broken was minimum at 6% NaHCo3 and 10% moisture content of grain.58.5 dehusked kernels were obtained at 6% NaHCo3 and 8% moisture content of grain.

Based on the above results conducted in the lab on stakes rice polisher, it was though proper to conduct large scale tests on mini dhal mill using 6% NaHCo3 concentration ,30 min.(summer) to 60 min.(winter) soaking and milling at 10% moisture content to get higher dhal recovery, minimum powder and minimum brokens losses.

For effective dhal mill operation, control of moisture content of grain is very important factor. Milling at very low moisture, produced more powder and milling at a very high moisture produces more tin hulled and less dal recoveries. Therefore, milling of grain in the neighborhoods of 10.5% moisture content is recommended for industrial scale operation to higher dhal recovery.

The treated samples at desired levels of concentration were supplied to Biochemistry Department for bio chemical analysis. The raw grain as well as oil treated grains were also supplied to meet the objectives defined earlier. The cooking qualities and experiments on mini dhal mill is in progress.

FINDINGS

Based on present findings:

- Treatment of pigeon pea grain should be done using 6%NaHCO3
- Milling at 10.5% moisture content on wet basis for high's dal recovery
- Dehusking of grain should be done at 8.5% moisture content on wet basis
- Socking for then 1hr should not be recommended

RECOMMENDATIONS

There are following modes for improving Arhar dal recovery:

1. Parboiling of pulses at different levels may be tried, which may improve milling efficiency as well as cooking quality.
2. Heating temperature and time may be further optimized for milling efficiency.
3. A continuous operating system may be designed and developed to carryout uniform treatment at optimized levels.
4. Better milling results may be obtained if arhar is first pitted and then oil smeared, heated and then tempered with other pretreatments. This pretreatment may be tried.

- Length of time for drying the grain for best milling operation of pigeon pea, experiments should be done to find out the length of time which will be required to reach to the required temperature and moisture content for different air temp., discharge rates, and static pressure.
- Study should be done on milling performance of precondition treatments by different methods at different moisture levels.
- Machine factors may also be studied which bring about dal milling losses. This will help in modifying the existing machines or give direction in designing new machines which can give better milling performance.

CONCLUSION

It has been well established by the study that at 6% NaHCO3 concentration & 10.5% moisture content the recovery of dal is highest however it has to be verified on scale up operation and field conditions.

SCOPE FOR FURTHER RESEARCH

Future research work on "Performance Evaluation of CFTRI Dal Mill" may be done on following lines:

1. Length of time for drying the grain for best milling operation of pigeon pea, experiments should be done to find out the length of time which will be required to reach to the required temperature and moisture content for different air temp., discharge rates, and static pressure.

2. Study should be done on milling performance of precondition treatments by different methods at different moisture levels.
3. Machine factors may also be studied which bring about dal milling losses. This will help in modifying the existing machines or give direction in designing new machines which can give better milling performance.

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APPENDIX

TABLE NO. 1: EFFECT UNTREATED OF PIGEON PEA GRAIN ON MILLING AT DIFFERENT MOISTURE CONTENT (CONTROL)

S.no.	Moisture content /By products	6 %	8 %	10 %	12 %
1.	Husked (gm)	721.5	754.5	750	700.5
2.	Unhusked (gm)	57.0	70.50	72.00	162.0
3.	Dal (gm)	228.0	273.0	304.5	219.0
4.	Brokens (gm)	85.5	88.5	72.0	145.5
5.	Quantity of powder produced(gm)	408.0	313.5	301.5	273.0

TABLE NO. 2: EFFECT OF ADDITION OF 4%NaCL ON MILLING OF PIGEON PEA AT DIFFERENT MOISTURE CONTENTS

S.n.	Moisture content /By products	6 %	8 %	10%	12%
1.	Husked (gm)	732.0	774.0	759.0	709.5
2.	Unhusked (gm)	30.0	33.0	36.0	172.5
3.	Dal (gm)	237.0	288.0	327.0	208.5
4.	Brokens (gm)	84.0	87.0	64.5	144.0
5.	Quantity of powder produced(gm)	417.0	318.0	313.5	265.5

TABLE 3: EFFECT OF ADDITION OF NaHCO3 ON MILLING OF PIGEON PEA AT DIFFERENT MOISTURE CONTENTS 4% NaHCO3 CONTROL

S.no.	Moisture content /By products	6 %	8 %	10 %	12 %
1.	Husked (gm)	777.0	846.0	819.9	741.6
2.	Unhusked (gm)	42.0	70.5	87.0	175.8
3.	Dal (gm)	208.2	229.5	279.0	205.5
4.	Brokens (gm)	72.0	72.15	69.9	151.5
5.	Quantity of powder produced(gm)	400.8	281.85	244.2	225.6

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