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# Effect of selected decorticated legumes protein on rheology of maize extrudate pastes

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Extrudates were formulated through the combination of decorticated Bengal gram, green gram and black gram with maize grits at 0, 5, 10 and 15% (w/w) level of substitution individually through indigenous single screw food extruder. The feed rate, feed moisture and length to diameter (L/D) ratio of the food extruder and screw speed were kept constant at 30 kg/h, 14% (w.b), 4:1 and 500 rev/min, respectively during the extrusion cooking. These legume incorporated maize extrudates pastes increased k-value (apparent viscosity) and decreased n-values (degree of Newtonian behaviour). In general, addition of legumes (plant protein) increased the viscosity. Black gram addition showed higher degree of fluctuations in rheological values.

**Keywords:** Paste, Extrudates, Bengal gram, Green gram, Black gram, Maize grit, Viscosity

Most cereal-legume blended extrudates exhibit complex and variable rheological behaviour like extrusion process, time dependence, blend levels, process conditions, shear dependence and viscoelasticity. In addition, factors such as temperature and concentration also influence rheological properties of extrudate pastes (Mercier et al 1989). Blending cereals and legumes achieve the well-known principle of protein complementation and offer a practical route to energy dense low-cost weaning foods (Harper and Jansen 1985). Pastes made from various extruded starches and maize grits exhibit non-Newtonian behaviour, becoming less shear at higher shear rates (Launay and Lisch 1983) and such information is critical in determining power requirements for engineering operations such as pumping and mixing of paste, in quality control of finished products, and in improving the process conditions. Therefore, in the present experiment, effect of decorticated legumes at different proportions with maize on rheological characteristics of extruded paste (through indigenous extruder) for its derived products has been studied.

## Materials and methods

The decorticated Bengal gram (*Cicer arietinum* L.), green gram (*Phaseolus aureus* Roxb) and black gram (*Phaseolus mungo* Roxb), purchased from the local market were cleaned and milled to pass through 12 mesh sieve (ASTM) in a roller mill. Bengal gram was blended with maize grits at 0, 5, 10 and 15% (w/w). The moisture content of each blend (4 kg) was adjusted to 14% (w.b), and conditioned to equilibrate for overnight as described earlier (Singh et al 2000). Before extrusion, the feed was allowed to ambient temperature (28-30°C) and then remixed. The extrudates were produced through heavy-duty indigenous single screw food extruder (BNF Mills, Batala, India). The length to diameter (L/D) ratio of the extruder was 4:1. The feed rate of the hopper was adjusted to 30 kg/h. The barrel was enrobed with cold/ tap water circulation to maintain the temperature. A cutter knife (45° angle) was operated with a separate DC motor. The screw speed was kept constant (500 rev/min) during extrusion cooking. The extruder barrel was fitted with 2.75 mm nozzle and a cutter. These decorticated legumes blended maize extrudates from the extruder were ground to powder individually, and passed through 52 mesh sieve (ASTM) for rheological measurements.

*Rheological measurements*: The rheological characteristic of extrudate paste was determined using a Brookfield viscometer (Model DV-II, Brookfield Engineering Inc., USA). The ground extrudate samples (30 g) were dispersed in distilled water (200 ml) and stirred for 5 min. After stirring, the extrudate paste was cooked at 80°C for 20 min in a water bath. The cooked samples were placed at 4°C for 15 min and subsequently at the ambient temperature (28-30°C) for 105 min. The shear rate range measured was 0.66 to 132/sec. Temperature was maintained at 27°C during measurement. Shear stress was measured continuously while shear rate was increased in steps. For each sample, duplicate suspension was made and apparent viscosity, shear rate, shear stress and torque were measured as described by Dave et al (1999). Experiments were replicated five times and statistical analysis was done using MS EXCEL 2000.

## Results and discussion

*Effect of legume addition on stress rate and apparent viscosity*: There was an increase in shear stress over the entire range of shear rate measured for 0, 5, 10 and 15% inclusion of legumes (Fig. 1). The samples were non-Newtonian, in

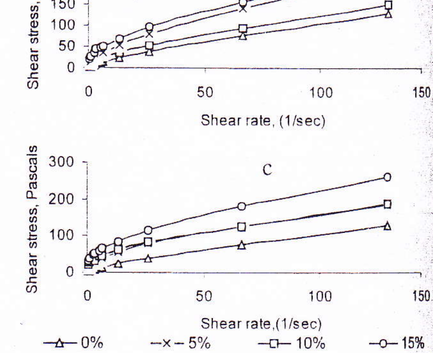


Fig. 1. Flow curve of maize extrudate paste incorporated with different levels of decorticated legumes (a) Bengal gram, (b) green gram, and (c) black gram with maize grits

Table 1. Apparent viscosity and flow curves of legumes incorporated maize extrudate pastes variables in coded units

| | Best fit equations | $R^2$ |
|---|---|---|
| | **Viscosity** | |
| Bengal gram | $Y_{0.66} = 0.4137\ e^{0.1173x}$ | 0.964 |
| | $Y_{6.6} = 0.1905\ e^{0.0769x}$ | 0.954 |
| | $Y_{66} = 0.1162\ e^{0.0325x}$ | 0.964 |
| Green gram | $Y_{0.66} = 0.2772\ e^{0.1590x}$ | 0.864 |
| | $Y_{6.6} = 0.2159\ e^{0.0866x}$ | 0.992 |
| | $Y_{66} = 0.1189\ e^{0.0494x}$ | 0.963 |
| Black gram | $Y_{0.66} = 0.5926\ e^{0.1561x}$ | 0.828 |
| | $Y_{6.6} = 0.2673\ e^{0.0961x}$ | 0.859 |
| | $Y_{66} = 0.1279\ e^{0.0524x}$ | 0.900 |
| | **Flow curves** | |
| Chick pea | $Y_0 = 3.3628\ SR^{0.7498}$ | 0.989 |
| | $Y_5 = 6.2802\ SR^{0.6500}$ | 0.995 |
| | $Y_{10} = 9.1509\ SR^{0.5677}$ | 0.996 |
| | $Y_{15} = 18.569\ SR^{0.4735}$ | 0.999 |
| Green gram | $Y_0 = 3.3628\ SR^{0.7498}$ | 0.999 |
| | $Y_5 = 6.2910\ SR^{0.6562}$ | 0.997 |
| | $Y_{10} = 12.944\ SR^{0.5661}$ | 0.998 |
| | $Y_{15} = 23.517\ SR^{0.4468}$ | 0.989 |
| Black gram | $Y_0 = 3.3628\ SR^{0.7498}$ | 0.999 |
| | $Y_5 = 17.077\ SR^{0.4756}$ | 0.997 |
| | $Y_{10} = 22.589\ SR^{0.4117}$ | 0.988 |
| | $Y_{15} = 33.392\ SR^{0.3968}$ | 0.987 |

$Y_{0.66}$, $Y_{6.6}$, $Y_{66}$ = Apparent viscosity of legume incorporated corn extrudate paste at 0.66, 6.6 and 66/sec shear rate, respectively; $Y_0$, $Y_5$, $Y_{10}$ and $Y_{15}$ = Shear stress (Pascals) for 0, 5, 10 and 15% legumes incorporation levels, respectively x = Legumes incorporation level, %; SR = Shear rate, (1/sec); $R^2$ = Regression coefficient

which it is always higher for 15% (w/w) incorporation legumes especially black gram followed by green gram and Bengal gram. The non-Newtonian behaviour, in which shear stress was not directly proportional to shear rate, has been attributed to the presence of high molecular weight substances in solution and/or to the dispersed solids in a fluid phase (Rao 1977). When samples are non-Newtonian, apparent viscosity values are highly dependant on the shear rate at which shear stress is measured. When raw maize is cooked, it gelatinizes, producing viscous gruels at low concentration and correspondingly low calorific density. In contrast, the precooked gruels made from extruded maize (76.0-91.6 kcal/100 ml) have medium viscosity whether reconstituted in cold water (instant) or heated after reconstitution (Jansen et al 1981). Therefore, apparent viscosity was calculated at shear rate of 0.66, 6.6, 66.0/sec. The relationship between the apparent viscosity and shear rate shows (Fig. 2) the effect of different concentration of legume up to 15% (w/w) with maize extrudates, on apparent viscosity. The pseudoplasticity of the paste and consistency index (k) increased with increasing levels of legumes incorporations. By the addition of legumes up to 15% there was an increase in apparent viscosity for shear rate between 0.66 and 66/sec. This was true at all three-shear rates. Although its fluctuation was more at 0.66/sec rather for 6.6 and 66/sec shear rate. Thus, at a constant shear rate, addition of all legumes (individually) showed the same pattern. Glicksman (1969) has noted that measurement of viscosity of non-Newtonian fluids at a single shear rate gives an incomplete description of flow. The best-fit equation and correlation coefficients were developed for Bengal gram, green gram and black gram incorporated to maize extrudate with respect to shear rate at 0.66, 6.6 and 66/sec (Table 1).

*The power law*: Fig. 3 shows shear stress-shear rate data plotted on double logarithmic plots for different proportions of decorticated Bengal gram, green gram and black gram incorporated maize extrudate paste. When second-order regression analysis was applied to these data, all three plots had strong correlation coefficients of above 0.99. Because of this high degree of linearity, it was concluded that all samples showed flow behaviour adequately described by the power law (Equation 1.):

$$\Im = k\ \gamma^n \qquad ...(1)$$

where, $\Im$ = shear stress, Pascals-sec; k = consistency coefficient, Pascals; $\gamma$ = shear rate $sec^{-1}$; n = flow behaviour, dimensionless.

The intercepts of the double logarithmic plots (Fig. 3) equal log 'k', while the slope of the plot equals 'n'. The entire shear stress-shear rate flow can thus be described by the values of

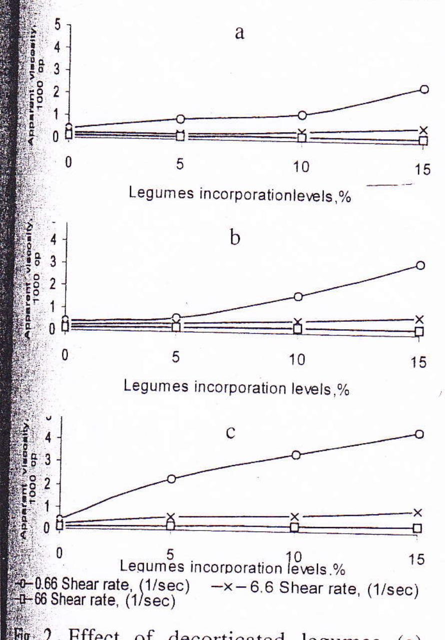


Fig. 2. Effect of decorticated legumes (a) Bengal gram, (b) green gram, and (c) black gram incorporated maize extrudates pastes, on apparent viscosity at three shear rates

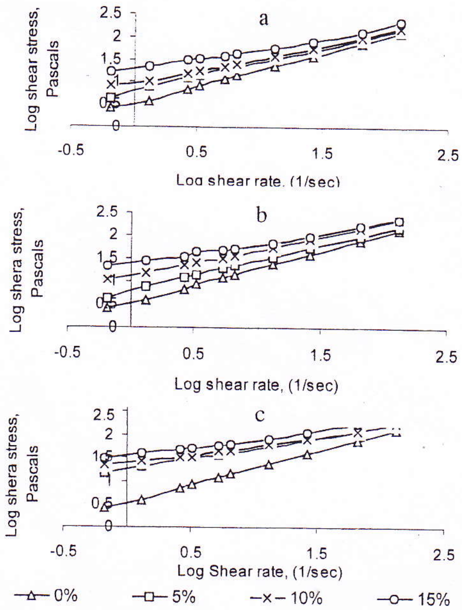


Fig. 3. Power law regression constants for different incorporation levels of decorticated legumes (a) Bengal gram, (b) green gram, and (c) black gram incorporated maize extrudate pastes

Table 2. Effect of decorticated legumes incorporated corn extrudate pastes and its components on power law constants

| Type | Legume level, % w/w | n | k | $R^2$ |
|---|---|---|---|---|
| Bengal gram | 0 | 0.750 | 0.336 | 0.999 |
| | 5 | 0.650 | 0.628 | 0.996 |
| | 10 | 0.568 | 0.915 | 0.995 |
| | 15 | 0.474 | 1.926 | 0.990 |
| Green gram | 0 | 0.750 | 0.336 | 0.999 |
| | 5 | 0.656 | 0.629 | 0.997 |
| | 10 | 0.566 | 1.294 | 0.998 |
| | 15 | 0.453 | 2.249 | 0.988 |
| Black gram | 0 | 0.750 | 0.336 | 0.999 |
| | 5 | 0.476 | 1.699 | 0.996 |
| | 10 | 0.411 | 2.258 | 0.986 |
| | 15 | 0.397 | 3.339 | 0.987 |

n = Flow behaviour, dimensionless; k = Consistency coefficient, Pascals; $R^2$ = Regression coefficient

When 'n'=1, the fluid is Newtonian and 'k' is the viscosity regardless of shear rate. If 'n' ≠ 1, the fluid is non-Newtonian. The peak consistency is apparently related to water by the biopolymer matrix. Decreasing values of 'n' below 1 indicate increasing degrees of psudoplasticity. When 'n' is less than 1, 'k' is 'apparent' viscosity (Toledo 1980, Urbanski et al 1982).

*Effect of legumes addition on power law constant*: There was a consistent increase in 'k' value for all increased legumes addition to maize extrudate paste. Though the addition of legumes beyond the levels may cause 'k' value to increase marginally, the Hedonic score values curtail to the incremental addition of legume blends, in product acceptability point of view. Among these legumes, Bengal gram was highly preferred over rest, scoring overall acceptance value of the extrudates more than 7 out of 9-point Hedonic scale in sensory evaluation (Balasubramanian et al 2005). It showed that legumes incorporated (in suppression to the extrusion process condition) maize extrudate paste also increased the viscosity of maize extrudate paste. Among the legumes, black gram addition (Table 2), showed a higher 'k' value as compared to Bengal gram and green gram addition and this can be ascribed to increase in viscosity of the aqueous phase. Also showed decreasing 'n' values for suspension of all components with increasing levels of legumes. The trend of 'k' values is inversely proportional to 'n' values. With addition of 15% (w/w) of legumes to maize extrudate paste also showed a higher degree of pseudoplasticity as shown by their low 'n' values. This shows that the legumes incorporated maize extrudates pastes lead to free association and pseudoplasticity is greater. Compared to pregelatinized products made by other treatments, the main difference in extruded starches is their reduced paste viscosities. In comparing drum drying with extrusion cooking, at a given level of water absorption, water solubility tends to be greater with extrusion cooking, and cooked viscosity tends to be greater with drum drying (Anderson et al 1969, Doublier et al 1986).

## Conclusion

Processing of the decorticated legumes (plant protein) incorporated extrudate paste to obtain different products such as cold/hot dessert attributes to shear stress, shear rate, consistency index and flow behaviour of the products. They display slow dispersion in cold water and rapid dispersion in hot water to form pastes of various consistencies, thus permitting their commercial use in instant foods.

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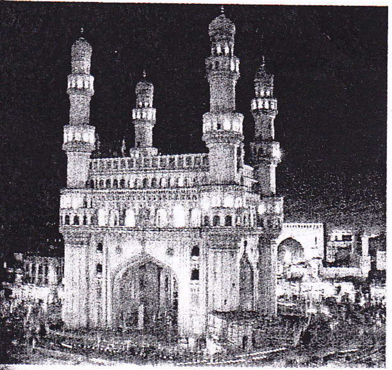

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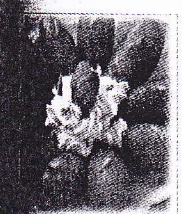

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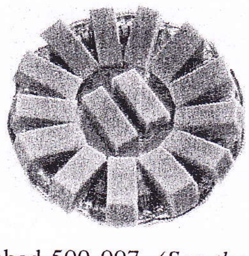

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