injected with the sample.

Selection of a particular apparatus configuration using 6W valve or solenoid pinch clamps will be determined by the type of process to be monitored and availability of parts.

Since the sequencer has a 40-step potential, it can be wired in the most desirable arrangement for repeat operations, up to 40 operations and 56 min. Our original design brought all contacts to terminal strips, so one can simply jumper from one terminal to another for "programming." A "plug-in" type board could also be used to speed up the instrument reprogramming for versatility. Other sequencers can be purchased to make practically any arrangement desired.

The apparatus makes a practical addition to equipment that can be used for monitoring vegetable oil process streams and reactions, such as hydrogenations (12).

Schematics and diagrams of the sequencer have been excluded for space-saving and simplicity but may be obtained by contacting the authors.

ACKNOWLEDGMENTS

The assistance and guidance of our in-house shops: e.g., photography, instrument, glass, are gratefully acknowledged.

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[Received February 19, 1980]

Potentialities of Oilseed Flours and Proteins for Replacing Black Gram Components in the Texture of Leavened Foods

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ABSTRACT

Defatted peanut and sesame flours in aqueous dispersions exhibit good surface activity ascribable to their protein content and comparable to that of black gram. Soy flour possesses twice as much surface activity as the other flours. Contrasted with black gram, foam matrices obtained with these dispersions are unstable to heat and have low viscosities. Addition of viscous polysaccharide stabilized the foam against thermal disruption. Oilseed flours appear to qualify as good alternatives for the surface active component and viscous hydrocolloids such as guar gum or gelatinized starch may be alternatives for the arabinogalactan of black gram. This combination effectively replaces the pulse in imparting the characteristic soft, spongy texture to leavened foods.

INTRODUCTION

Oilseed flours are the most promising protein sources to augment the lean food protein supplies in the burgeoning populations of developing countries whose staple foods are cereals, millets and tubers. Many of the oilseed proteins can supplement (1) the nutritive value of cereal proteins because of their high lysine content. Even in advanced countries there is an increasing trend toward greater use of vegetable proteins (2-7), particularly the oilseed meals and protein isolate derivatives, for fabricating animal feeds and human foods (8-10) such as baked foods, snack foods, simulated animal foods and emulsifiers. For these purposes, either the natural functional properties of the proteins are exploited or their properties modified by chemical, enzymatic or physicochemical means (11-13).

In earlier publications (14-17) we have demonstrated that the soft, spongy texture of leavened food preparations such as the *idli*, which contains black gram, results from the cooperative functioning of the highly surface-active proteins (15) and the highly viscogenic arabinogalactan (16) present in the legume. The arabinogalactan helps hold the leavening gases and prevents disruption of the protein-foam (spongy texture) by heat at culinary temperatures (17). In the follow-up studies, these observations have been extended to ascertain the feasibility of replacing the foam-forming protein components with oilseed flours and the other requirements for the effective generation of the spongy texture analogous to the leavened foods based on the legume. Preliminary examination indicated that defatted peanut, sesame and soybean had adequate surface activity and further studies were confined to these readily available oilseeds. The results are discussed in this communication.

MATERIALS AND METHODS

Peanut, sesame and soybean seeds were purchased from the local market, cleaned and stored at 5-7 C in sealed containers until use.

Peanut seeds were dried at 35-40 C for 2-3 hr, decuticled, flaked and solvent-extracted in Soxhlet apparatus with petroleum ether (40-60 C bp) to remove the fat. The residue was air-dried and powdered in an Apex grinder to get peanut flour (80 mesh).

Sesame seeds were soaked in water for 10-12 hr at room temperature (22-25 C), drained and dehusked by rubbing over a gunny bag. Seeds were air dried and winnowed/aspirated to remove the husk, flaked, defatted and powdered to get sesame flour.

Soybean seeds were dehusked, split and flaked after adjusting the moisture to 10-12%, then defatted and powdered to form soybean flour. Black gram flour (100

TABLE I

Surface Activities of Peanut, Sesame and Soybean Flours

	Peanut flour	Peanut flour[a]	Sesame flour	Soybean flour	Black gram flour
Total protein (%)	55	55	40	50	25
5% NaCl soluble proteins (%)	45	40	35	45	17
Activity u/g x 10^{-3}	7- 8	6-7	7- 8	14-15	5-6
Specific activity/mg protein	18-20	15-16	20-22	30-32	20-22

[a]A sample of expeller-pressed cake from peanut was washed with petroleum ether, air-dried and powdered to obtain peanut cake flour. This was also used in additional experiments for comparison.

mesh) and rice semolina (30 mesh) were prepared as described earlier (14).

Protein content of the NaCl extracts of defatted flours was determined according to Lowry et al. (18) and surface activity was determined using a Stiepel foam meter (14). Viscosities of flour dispersions and their batters were determined in a Brook-field viscometer (17). Stabilization of the foam formed by peanut flour dispersion with guar gum (Dealca P/225), arabinogalactan of black gram and soluble starch before and after gelatinization was tested as described earlier (17). Batters with different proportions of defatted flours were mixed with appropriate amounts of D-glucono-δ-lactone, $NaHCO_3$ and 0.5-0.7% guar gum and steamed to get test *idli* preparations. Their bulk densities were determined as described earlier (14).

RESULTS AND DISCUSSION

As indicated in our previous studies (14-17) the 2 functional parameters to be used in judging the suitability of any contemplated substitutes for black gram are surface activity and viscogenicity in aqueous medium. These criteria have been applied to the oilseed flours.

Surface Activity

The surface activity of the oilseed flours along with their total and saline-extractable protein content are given in Table I. Peanut flour and sesame flour had the same activity content, which was slightly higher than that of black gram, whereas soy flour was twice as active as these flours. The specific activities (sp act) of the proteins of the peanut and sesame flours were slightly less than the sp act of the proteins of black gram. In all these flours, the major portion of the activity was concentrated in the 40-75% (w/v) $(NH_4)_2SO_4$ precipitable protein fraction with a 3-4-fold increase in sp act similar to the properties of black gram. Further studies on the purification of these proteins, the amino acid make-up and physicochemical properties of the purified proteins would help reveal structure/surface activity interrelationships.

Viscosity

Figure 1 shows the viscosities of the aqueous dispersions of the oilseed flours as compared with those of black gram; Figure 2 represents the viscosities of *idli*-type batters containing rice semolina with varying proportions of these flours. The viscosities of the oilseed flour dispersions were much lower than those of black gram of corresponding strength. These differences were further accentuated in the batters because the rice semolina abstracts and binds the water from the medium, which increases the effective concentration of the highly viscogenic arabinogalactan hydrocolloid present in the legume (Fig. 2).

The data in Table I and Figures 1 and 2 clearly show that at isosurface-active levels the oilseed flour dispersions/batters have very low viscosities compared with black gram dispersions whereas at isoviscous levels they have very high surface activity. At a level of 33% black gram flour in the batter—an optimal proportion for obtaining a satisfactory steamed pudding or *idli*—the surface activity of peanut and sesame seed flour batters would be one and one-half times and that of soy flour would be twice that of black gram flour dispersions.

Foam Stability

The foams formed by the aqueous dispersions of oilseed flours were completely disrupted by heating to the boiling point. This observation was consistent with their low viscosities. The foam matrix in these experiments could be stabilized by adding viscogenic hydrocolloids (0.5-0.7%) as shown by the results presented in Figure 3. The role of arabinogalactan of black gram (Fig. 3d,e) or guar gum (Dealca P/225) (Fig. 3b,c) or gelatinized soluble starch

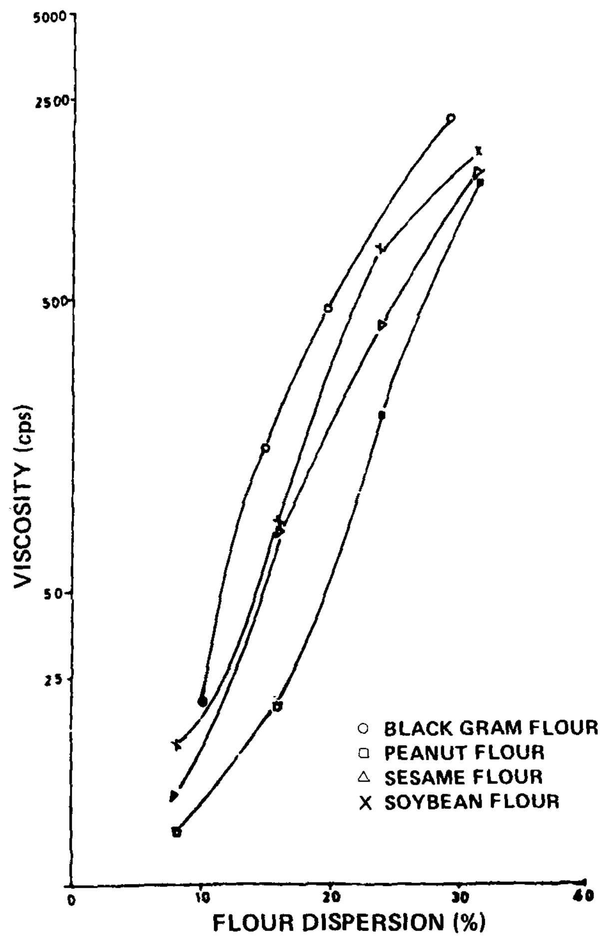

FIG. 1. Viscosities of defatted flour dispersions.

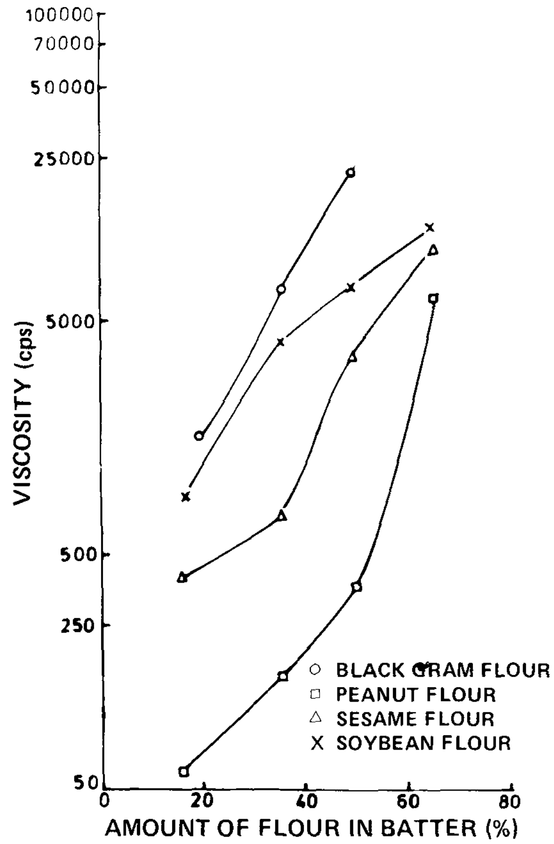

FIG. 2. Viscosities of batters containing rice semolina with different proportions of defatted flours.

(Fig. 3g,h) at isoviscous concentrations is illustrated with peanut flour. Contrasted with gelatinized soluble starch, ungelatinized soluble starch (Fig. 3i,j) at corresponding levels fails to confer any protection on the foam against thermal disruption; this confirms that viscosity is the functional factor involved in the protective action of the hydrocolloids. Observations with other oilseed flours were similar. However, these hydrocolloids were ineffective in protecting (against thermal disruption) the foam matrices formed by synthetic detergents.

Bulk Density and Texture of *Idlis*

As expected with the low viscosities, steaming the oilseed flour batters resulted in highly puffed-up preparations that were too loose and floury and lacked binding or adhesion. Such puddings could not be handled for bulk density determination or other measurements. Addition of 0.6% guar gum was effective in stabilizing the preparations. The bulk density of puddings prepared at 0.6% concentration of the gum in the final batter with varying proportions of the flours are given in Figure 4, which includes the data obtained with black gram flour as a reference. Notice that in the case of black gram, both the surface-active proteins and arabinogalactan increase continually as the proportion of the legume is increased in the batter, whereas in the case of the oilseed flour batters the proportion of the flours (and hence the protein surfactants) increases continually against a constant level of gum in the mix. The lowering in bulk density of the puddings with increasing proportions of the proteinaceous oilseed flours is obvious. The surface activity and viscosity of peanut cake flour (expeller-pressed cake flour was used for comparison) was 15-20% lower than that of the defatted flour prepared in the laboratory. The bulk densities of the puddings were higher to the same extent. Heat treatment during oil expelling may be mainly responsible for these adverse effects. The results indicate that some adjustment of the heating conditions are needed to obtain defatted flour best suited for producing the spongy texture in food products.

The extent of lowering in bulk density obtained with 33% black gram flour in the batter is attained with 18% soy flour, 20% sesame flour and 25% peanut flour. Porosity was also optimal at these levels (Fig. 5); the porosity and sponginess were more pronounced with soya flour. On the contrary, a sample of peanut flour partially deproteinized (containing 7-8% protein after treatment with pronase) had low surface activity and was unsatisfactory with respect to both lowering in bulk density (bulk density

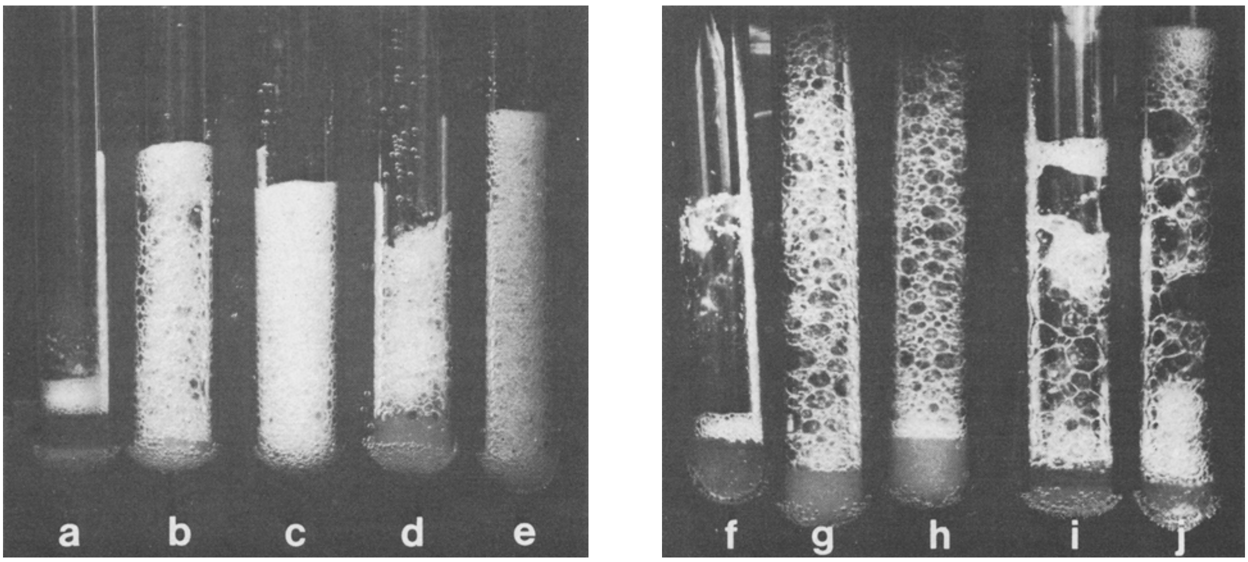

FIG. 3. Stabilization of foam formed by peanut flour against thermal disruption. Aqueous dispersions of 30 mg flour/ml were tested at 95 C in presence of $NaHCO_3$ (0.5 ml of 5% solution) and citric acid (0.5 ml of 5% solution) as in situ sources of CO_2. (a) no polysaccharide, (b and c) 0.5 and 1.5% of guar gum (Dealca P/225), respectively, (d and e) 0.5 and 1.5% of arabinogalactan from black gram, respectively, (f) no polysaccharide, (g and h) 0.8 and 2.4% of gelatinized soluble starch, respectively, (i and j) 0.8 and 2.4% of ungelatinized soluble starch, respectively.

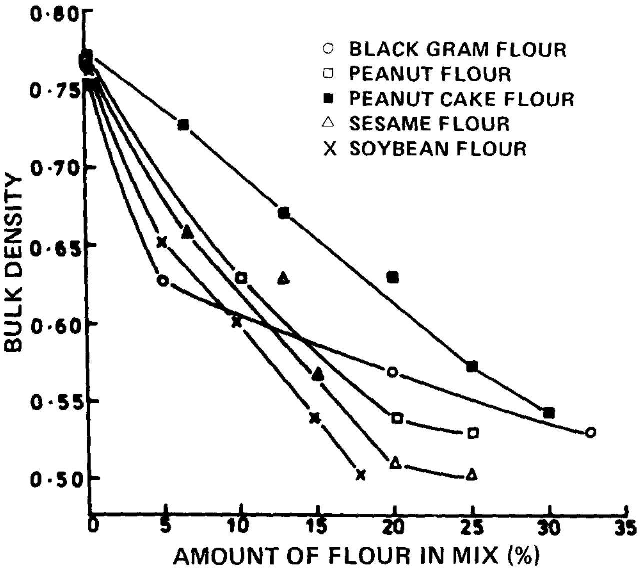

FIG. 4. Bulk densities of test *idli* preparations containing defatted flours. Total weight of solids was 15 g in each experiment. 1.8 Parts of water, 25 mg of D-glucono-δ-lactone and 12.5 mg of $NaHCO_3$/g of mix were added and mixed well. Guar gum (Dealca P/225) was also added to the dispersion (0.6%) before steaming. A sample of expeller-pressed cake from peanut was washed with petroleum ether, air-dried and powdered to get peanut cake flour. This was also used in the above experiments for comparison.

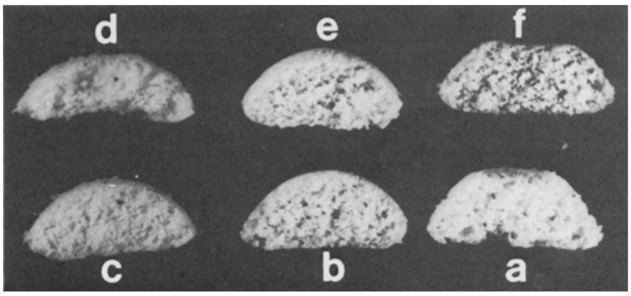

FIG. 5. Cross sections of test *idli* preparations containing defatted flours. (a) Rice semolina control (RS), (b) RS + black gram flour, (c) RS + peanut flour, (d) RS + partially deproteinized peanut flour (peanut flour was treated with amylase and pronase to obtain partially deproteinized flour for test purposes), (e) RS + sesame flour, (f) RS + soybean flour.

nearer that of rice semolina control) and porosity of the final product, which was rather hard. At higher proportions of flours than those indicated in Figure 4, the preparations were floury and difficult to handle for bulk density measurements because of the disproportionate rise in surface activity in relation to the viscosity of the batters.

Functional properties of the constituents of wheat in relation to bread making have been extensively studied (19). Soy flour protein has been shown to possess important functional properties (12) and is used in several food preparations, some of which also contain added gums, such as guar gum (20). Both surface activity and viscosity are essential for generating a porous and spongy texture in food preparations is clearly indicated by these studies (19,12) and also by our earlier work (14,17). It is notable that this type of texture could be imparted by (a) functionalities associated with similar biological entities such as the gliadin (21) and glutenin (22) of wheat; or (b) different entities such as the globular protein (14,15) and arabinogalactan (16,17) of black gram; or (c) by different moieties from entirely different natural sources that are used at functionally optimal levels, as indicated by these studies. Product development based on these findings would require further standardization with specific ingredients chosen as well as attention to flavor and other accessory factors.

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[Received June 14, 1979]