Breadmaking Properties of Composite Flours of Wheat and Faba Bean Protein Preparations[1]

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ABSTRACT

Cotyledon flour of faba beans (*Vicia faba* L.) and three different protein preparations (concentrate, isoelectric isolate, and micellar mass) were used to prepare composite flours with wheat flour milled from two varieties of hard red spring wheat (cultivars Neepawa and Glenlea). All composite flours contained approximately 20% protein based on maximum computed protein efficiency ratio. Differential scanning calorimetry results showed that the micellar mass protein appeared to be quite different (less denatured) from the protein in the isoelectric isolate. Farinograph and extensigraph results on doughs of composite flours showed a significant modification of rheological properties by the addition of each nonwheat component. Baking results indicated that all nonwheat components except the protein micellar mass had a negative effect on loaf volume of both wheat varieties. It was concluded that the protein micellar mass is compatible with wheat gluten in functionality for breadmaking.

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A great deal of attention has been paid to the potential use of legume flours as bread fortifiers (McConell et al 1974; Patel and Johnson 1974, 1975; Patel et al 1977; D'Appolonia 1977; Fleming and Sosulski 1977, 1978; Finney et al 1980; Hsu et al 1980, 1982). Although legume flours appear promising in terms of fortification, their use is not straightforward. Their beany flavor, content of digestion inhibitors, and high starch content relative to protein were cited as causes of major problems. These problems can be largely overcome by partially or completely purifying legume protein to obtain a concentrate or isolate (Patel et al 1977; Fleming and Sosulski 1977, 1978).

According to Jeffers et al (1978), fortification of wheat and corn flours with legume flours improves the nutritional quality in the composite flour. In addition, Raidl and Klein (1983) showed that dilution of wheat gluten by the addition of soy or field pea flour affects yeast bread more than chemically leavened quick bread.

The present study extends published information on composite wheat-based flours containing faba bean (*Vicia faba* L.) flour, protein concentrate, and protein isolate and presents new information on a novel protein preparation, protein micellar mass, that appears to have good functionality in breadmaking.

MATERIALS AND METHODS

Materials

Wheat flours (WF) were milled from grain of two Canadian varieties of hard red spring wheat, Neepawa and Glenlea. These varieties were selected to represent widely different dough mixing properties. Neepawa is a typical variety of the Canada red spring class, whereas Glenlea has very strong dough mixing properties and has been licensed into the Canada utility class. Wheat was tempered overnight to 15.5% moisture content and milled into straight-grade flour (extraction rate of 72%) on a Buhler experimental mill.

Faba beans (cultivar Diana) were milled into flour (FF) by the procedure of Watson et al (1975). Faba bean protein concentrate (PC) was prepared from the flour by air classification on an Alpine

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model 132 Mikroplex air classifier. Protein isoelectric isolate (PII) was prepared from PC as described by McEwen (1974). Faba bean protein micellar mass (PMM) was prepared from PC using the method of Murray et al (1981). According to this method, protein in PC was dissolved in dilute salt (NaCl) solution (salting-in) and then precipitated by increasing the ionic strength (salting-out). This procedure produces a protein that retains essentially all of its native properties.

Composite flours were prepared by blending dry materials in proportions calculated to produce a blend of 20% protein. This percentage was selected because it gives the maximum computed protein efficiency ratio (C-PER) calculated according to Alsmeyer et al (1974) using published amino acid composition data for the wheat and faba bean varieties under study (Butaki 1977, Cepeda 1981). The protein contents of basic materials used in the preparation of composite flours are given in Table I.

Chemical Analyses

Moisture content was determined by the Brabender moisture tester (at 130° C for 1 hr in an air oven). Total nitrogen was determined by the macro Kjeldahl method (AACC 1983, method 46-12) and converted to protein by multiplying the nitrogen values by 5.7 for wheat flour and by 5.85 for faba bean products (Murray et al 1981).

Differential Scanning Calorimetry

Analyses were made on aqueous slurries (20%, w/w) of PII and PMM on a Dupont model 990 differential thermal analyzer equipped with a model 910 differential scanning calorimetry (DSC) cell. Samples (10 mg) were placed in a preweighed DSC pan, hermetically sealed, and weighed to an accuracy of 0.01 mg. Samples were scanned at a heating rate of 5° C min^{-1} using instrument sensitivity of 0.01 $mcal \cdot s^{-1}$ in^{-1}. The reference pan contained sufficient sand to approximate the heat capacity of the sample. The cell was flushed with nitrogen at a rate of 30 ml min^{-1} to ensure a stable atmosphere. To obtain peak areas, base lines were constructed as a single straight line from the beginning to the end of the endotherm, and the area under the peak was obtained with a planimeter. To determine the enthalpy of the reaction, which is generally accepted as the enthalpy of denaturation (ΔH_6) for proteins (Arntfield and Murray 1981), the following equation was used:

$$\Delta H_d = A/MCP\ (60\ BE\ \Delta QS),$$

where ΔH_d = enthalpy of denaturation ($mcal \cdot mg^{-1}$), A = area ($in.^2$), B = time base (min^{-1}), and E = cell calibration coefficient. ΔQS = y-axis range ($mcal \cdot s^{-1}$ in.), M = sample mass (mg), C = sample concentration (%, w/w), and P = protein content of sample.

Rheological Properties of Dough

Farinograms, extensigrams, and amylograms were determined by AACC approved methods 54-21, 54-10, and 22-10, respectively (AACC 1983).

Baking Tests

The bread formula was: 100 g (14% mb) of flour, 3.0 g of compressed yeast, 2.0 g of salt, 5.0 g of sugar, 3.0 g of shortening, 0.1 ml of barley malt syrup, 0.1 g of ammonium phosphate (mono basic), 20 ppm of potassium bromate, and water equivalent to farinograph absorption less four percentage units.

The dough ingredients were mixed in a Grain Research Laboratory (GRL) mixer (Hlynka and Anderson 1955) at 130 rpm for 4 min. The resultant dough was folded 20 times and fermented for 2 hr at 30° C and 90% relative humidity. It was given the first punch after 55 min, passed once between sheeting rolls set at 9/32 in., and given a similar second punch after an additional 40 min. After another 25 min, the dough was sheeted by passing twice through the sheeting rolls (first at a setting of 9/32 in. and second at 3/16 in.), mechanically molded, placed into pans, and given a final proof for 55 min at 30° C and 90% relative humidity. The dough was baked for 25 min at 205° C (Cepeda 1981). Loaf volume was determined by rapeseed displacement.

Experiments were performed in duplicate, and the coefficient of variation (C.V.) was calculated according to Steel and Torrie (1960).

TABLE I
Protein Contents of Basic Materials

Materials	Protein Content[a] (%, db)
Wheat flour	
Glenlea	14.7
Neepawa	16.4
Faba bean preparations	
Flour	30.8
Protein concentrate	54.4
Isoelectric isolate	73.5
Micellar mass	76.5

[a] For wheat, N × 5.7; for faba bean, N × 5.85.

RESULTS AND DISCUSSION

DSC Results

Thermograms (Fig. 1) of PII and PMM were quite different. According to Arntfield and Murray (1981), the thermogram of PII indicates that this protein had suffered a substantially greater degree of denaturation during its preparation than PMM. The enthalpy of denaturation was 2.43 and 4.40 $cal \cdot g^{-1}$ for PII and PMM, respectively. The temperature of denaturation was 82 and 97° C for PII and PMM, respectively.

It is known that factors such as acid and alkali used in PII preparation may be responsible for changes in the secondary, tertiary, or quaternary structure of the protein. Such changes are usually referred to as denaturation and are known to affect functional properties of proteins such as water absorption (Vose 1980, Narayana and Rao 1982), fat absorption (Sathe and Salunkhe 1981), oil emulsification capacity (Vose 1980, Sathe et al 1982), and nitrogen solubility index (Vose 1980). Denaturation usually affects the applicability and functionality of plant food proteins (Wu and Inglett 1974).

Farinograph Results

Farinograph absorption of the Neepawa-faba bean composite flour (Fig. 2) was about two percentage units lower than that of the control. Addition of PC, PII, and PMM produced a further reduction in absorption, the largest being five units for PII. The coefficient of variation was insignificant (3.31%) among the different treatments. Results for the stronger Glenlea flour appear to be quite different; the addition of the protein preparations had no effect on water absorption (C.V. = 0.14%).

Arrival time decreased for Neepawa blends but increased for Glenlea blends. Dough development time showed similar trends. Addition of nonwheat component decreased the stability and increased the mixing tolerance index for both wheat varieties.

Farinograph results suggest that the time at which the Glenlea

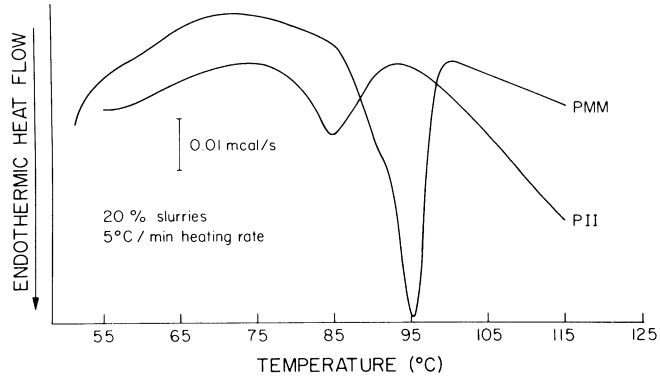

Fig. 1. Differential scanning calorimetry thermograms for faba bean protein micellar mass (**PMM**) and protein isoelectric isolate (**PII**).

curve levelled off reflects hydration time, not dough development time. When the gluten of Glenlea was weakened by dilution with substances that do not form gluten, the doughs showed a true dough development peak. As expected, the peak for the Glenlea blends appeared much later than for the Neepawa blends. The higher water absorption of the Glenlea control sample, despite its lower protein, is attributed to its high starch damage (data not shown).

Extensigraph Results

Extensigraph results (Table II and Fig. 3) showed that faba bean flour decreased the resistance to extension (elasticity) without affecting the extensibility. Composite flours from protein preparations produced dough with significantly different rheological properties from those of control dough. The C.V. values for extensibility/resistance ratios ranged from 57.14 to 62.57% and from 42.21 to 61.95% for composite flour with Neepawa and Glenlea wheat flour, respectively.

Amylograph Results

Data presented in Table II indicate that Glenlea flour had a significantly lower amylograph peak viscosity (200 BU) than that of Neepawa flour (820 BU). This difference was maintained for all of the composite flours. The lower amylograph peak viscosity is consistent with its somewhat higher inherent α-amylase activity.

Addition of the nonwheat component produced a decrease in peak viscosity for Neepawa (C.V. = 16.10%), but viscosities for composite flours of Glenlea increased with faba bean flour and PII (C.V. = 25.98%) remained approximately constant for PC and PMM.

Baking Results

Data given in Table II and Figure 4 show that the protein

TABLE II
Extensigraph Extensibility/Resistance (E/R) Ratios, Amylograph Viscosities, and Loaf Volumes of Neepawa and Glenlea Wheat Flours and Their Blends

Flour Blend[a]	Extensigraph (E/R) 45 min	90 min	135 min	Amylograph Viscosity (BU)	Loaf Volume (cm^3)
Neepawa wheat flour					
Control (WF)	0.85	1.47	1.27	820	820
+ FF	0.49	0.53	0.61	540	745
+ PC	0.93	0.97	1.23	640	710
+ PII	2.25	2.83	3.40	780	490
+ PMM	1.43	2.08	2.44	690	820
C.V. %	57.14	57.59	62.57	16.10	18.92
Glenlea wheat flour					
Control (WF)	3.88	3.06	3.79	260	635
+ FF	1.01	0.78	1.10	310	560
+ PC	1.04	1.97	2.23	260	525
+ PII	2.86	3.35	3.66	440	420
+ PMM	1.44	1.60	2.38	260	570
C.V. %	61.95	49.30	42.21	25.48	14.57

[a] WF: Wheat flour; PII: faba bean protein isoelectric isolate; FF: faba bean flour; PMM: faba bean protein micellar mass; PC: faba bean protein concentrate.

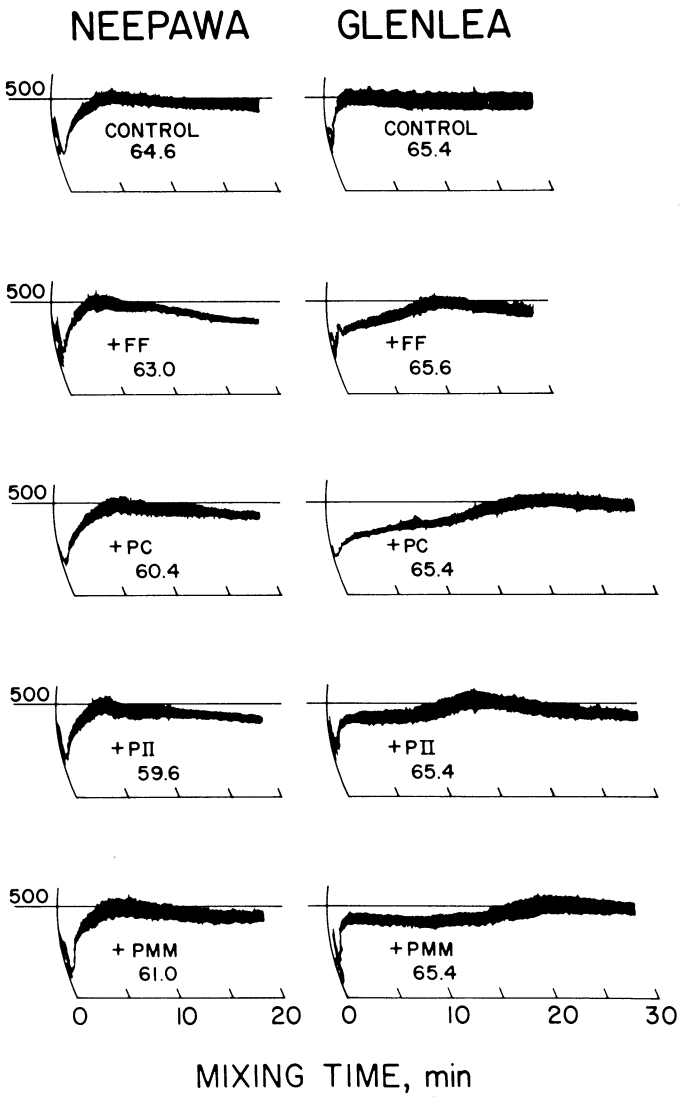

Fig. 2. Farinograms for control and composite flours. Numbers are farinograph absorptions.

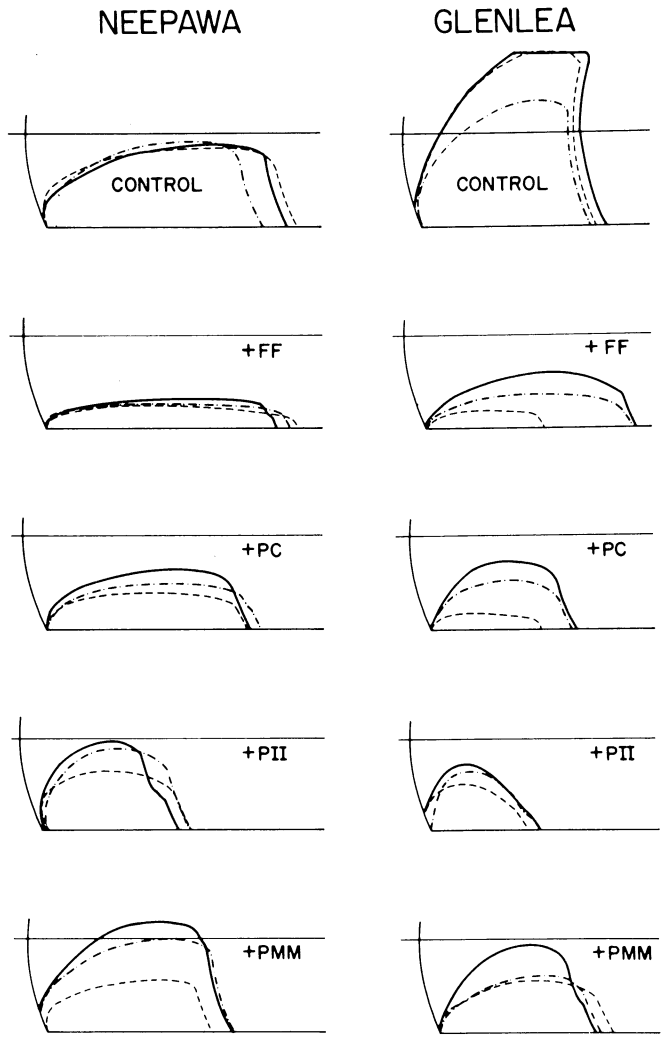

Fig. 3. Extensigrams for control and composite flours: 45 min (——), 90 min (– · – · –), and 135 min (– — – —).

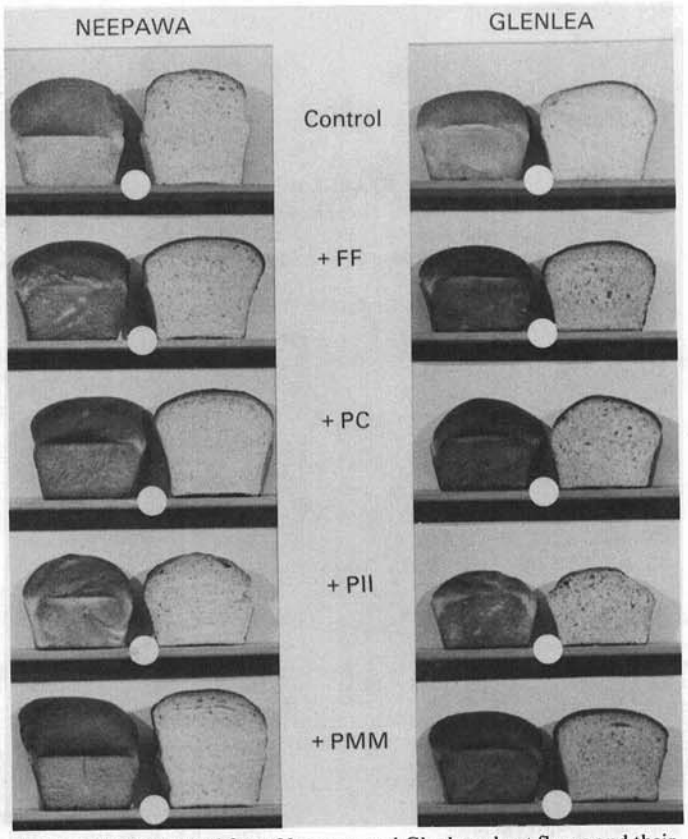

Fig. 4. Breads prepared from Neepawa and Glenlea wheat flours and their composites with faba bean flour (**FF**), protein concentrate (**PC**), protein isoelectric isolate (**PII**), and protein micellar mass (**PMM**).

preparations differed substantially in their effect on loaf volume. For Neepawa, PMM gave a loaf volume equal to that of the control, and PII gave the lowest loaf volume. The same effect was found for the Glenlea composite with PII. In contrast, PMM decreased the loaf volume of the Glenlea composite by approximately 10%. This negative effect appears to be consistent with the decrease in the extensigraph resistance to extension. The C.V. values for loaf volume were 18.92 and 14.57% for Neepawa and Glenlea composites, respectively.

Farinograms indicate that FF, PC, and PII weakened dough properties and decreased the water absorption for Neepawa, whereas PMM had essentially no effect on the mixing curve but also decreased water absorption. For the Glenlea composites, the effect of all additives on the farinograph properties appeared to be similar. Whereas this is generally consistent with the baking results, the results for PMM do suggest that its overall effect in composite forms depends on the strength (dough development time) of the base flour.

Baking results were consistent with the DSC results, which indicated that during processing the protein in PMM acquired (or retained) more of the relevant functional properties than the protein in PII. PMM appears to be compatible with wheat gluten in functionality for breadmaking. This functionality was probably developed during the preparation process, because it appeared to be absent in the faba bean flour and PC from which PMM was prepared. However, the possibility that the flour and PC contain a suppressing factor, which was eliminated during preparation of PMM, cannot be discounted on the basis of evidence presented. Data concerning the deleterious effects of PII on loaf volume are in agreement with those of Hsu et al (1980, 1982). These workers showed that fortification of wheat flour with faba bean flour at 15% level produced a small loss (9–12%) in loaf volume, crumb grain, and flavor, whereas replacement of wheat flour with 5 or 8% PII had deleterious effects on loaf volume and crumb grain. On the basis of data presented in this article, PMM appears to be the most promising fortification product from faba beans in terms of functionality in breadmaking.

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