# Preparation and Properties of Spray-Dried Pea Protein Concentrate-Cheese Whey Blends

P. R. PATEL,[1] C. G. YOUNGS,[2] and D. R. GRANT, Department of Chemistry and Chemical Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada S7N 0W0

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## ABSTRACT

An air-classified pea protein concentrate (PPC) was blended with cheddar cheese whey (W). The resulting pea protein concentrate-cheese whey (PPCW) blend was given a low heat (LH) treatment at 63°C for 30 min or a high heat (HH) treatment at 85°C for 20 min and then concentrated and spray-dried. A third blend was prepared by giving only the W an HH treatment before blending it with the PPC. Samples of LH-PPC, HH-PPC, LH-W, and HH-W were prepared separately under similar conditions. The functional properties of PPCW blends were compared with those of LH-PPC, HH-PPC, LH-W, HH-W, two commercial nonfat dry milks (NDM) given low and high heat treatment, and two commercial soy-whey blends. The foregoing samples were also compared as bread ingredients. Among the blends, LH-PPCW had higher water hydration capacity, oil absorption, oil emulsification, and greater foam stability than did the two NDM or the soy-whey blends. Loaf characteristics of breads containing 6% LH-PPCW were equivalent to those of breads containing NDM and were slightly better than those of breads containing soy-whey blends. Sensory evaluation showed no significant difference in flavor between breads containing LH-PPCW, HH-NDM, and the soy flour-whey blend.


In recent years considerable interest has been shown in field peas as a high protein crop for Western Canada. The scope for using peas has been increased by the development of a fine-grinding and air-classification process that yields a starch-rich fraction and a pea protein concentrate (Anonymous 1974).

Vegetable protein concentrate may be blended with cheese whey and dried to give replacement products for nonfat dry milk (Guy et al 1969) with special utility in the baking industry (Scanlon 1974, Singleton and Robertson 1974, Thompson 1977).

The object of this study was to prepare pea protein concentrate-cheese whey (PPCW) blends using conventional equipment for processing nonfat dry milk (NDM). The properties of the blends were evaluated in comparison with those of two NDM and two commercially available soy-whey blends. Comparisons were also made with the individual starting materials after similar processing. All these products were tested as ingredients in bread.

The preparation of PPCW blends removes the ripe pea flavor associated with air-classified pea protein concentrate (PPC). The evaporation and spray-drying process provides the combination of moisture and heat known to be effective in eliminating this objectionable flavor (Anonymous 1974). From the standpoint of handling, additional advantages resulted from coprocessing whey and PPC. Certain difficulties encountered in spray drying either whey or PPC slurries alone did not arise in processing the PPCW blends.

## MATERIALS AND METHODS

### Materials

PPC was prepared commercially from field peas (*Pisum sativum* L. cv. Trapper) by the procedure of Youngs (1975). Pasteurized sweet cheddar cheese whey (W) was provided by a local dairy. The W was held at 55°C for 1 hr to permit residual curd to settle. After removal of fat, the W was pasteurized at 74°C for 15 sec. Two samples of NDM were included in this study for comparative purposes. One was a high heat NDM (HH-NDM) of the type designed for the bakery industry, and the other was a conventional low heat product (LH-NDM). Both were obtained from commercial sources. Also included as control samples were two commercial products: a soy flour-sweet whey blend (SFW), Provide P29, from Swift and Co. and a soy protein isolate-caseinate-whey blend, Dari-Pro-35, from Ralston Purina Co.

[1]Interdisciplinary Food Science Program, University of Saskatchewan, Saskatoon. Present address: Diagnostic Chemicals Ltd., Charlettetown, P.E.I., Canada C1A 4H5.

[2]National Research Council of Canada, Prairie Regional Laboratory, Saskatoon.

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### Preparation of PPCW Blends and Control Samples

The PPCW blends were prepared as described in Fig. 1. A slurry composed of 114 kg of W and 9.1 kg of PPC was mixed thoroughly and adjusted to pH 6.8 with a 10% aqueous suspension of lime. The proportions of W and PPC in the blends were chosen to give a product in which the ratio of whey proteins to pea proteins would approximate that of whey proteins to caseins in NDM. The blend was then subjected to one of two heat treatments, followed by concentration to 40–45% total solids in an APV Junior plate evaporator at 50°C and a vacuum of 26 in. of Hg. Finally, the

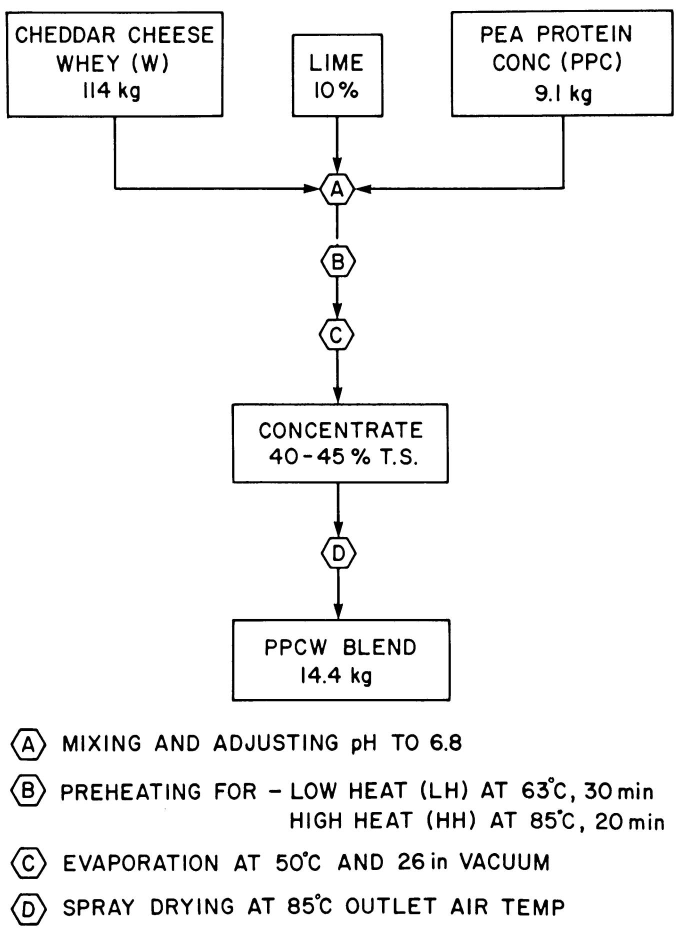


**Fig. 1.** Schematic flowsheet for preparation of pea protein concentrate-cheese whey blends. T. S. = total solids.

concentrated slurry was dried in a Proctor Schwartz spray dryer with an inlet air temperature of 230° C. The feed rate was controlled to give an outlet air temperature of 85° C. The heat treatment before evaporation, either low heat (LH) at 63° C for 30 min or high heat (HH) at 85° C for 20 min, yielded LH-PPCW and HH-PPCW, respectively. The time-temperature relationships for the heat treatments were selected on the basis of data for the NDM reported by Hall and Hedrick (1971). The HH treatment was expected to extensively denature whey proteins and resembled that given to bakery grade NDM. The LH treatment was not expected to denature the whey proteins adequately for use in bread.

A third blend was prepared by giving and HH treatment to the W only before mixing it with the PPC. Consequently, the PPC in this blend received no preheating. This product was designated HH-W+PPC.

Control samples LH-PPC and HH-PPC were prepared by the procedure described in Fig. 1 except that W was replaced by an equal volume of water and the concentration did not exceed 30% total solids. Similarly, LH-W and HH-W were prepared as additional controls by omitting the PPC. In drying the W alone, an additional processing step was included. The concentrated W was held overnight at 24° C to induce lactose crystallization.

**Methods of Analysis**

Proximate composition was determined by standard AACC (1961, 1976) procedures for moisture (method 44-40), crude protein (method 46-11), crude fat (method 30-25), crude fiber (method 32-15), and ash (method 08-01). Amino acid analysis was performed on a Beckman model 120C analyzer. The procedures for protein hydrolysis and for the analysis of tryptophan, methionine, and cysteine were those described by Sosulski and Sarwar (1973). Chemical score was calculated as described by Block and Mitchell (1946). The essential amino acid index was calculated by the procedure of Oser (1951). The FAO/WHO (1973) provisional pattern of eight essential amino acids was used as a reference protein.

Nitrogen solubility indices were determined by the AACC (1976) method 46-23 modified as follows: pHs were adjusted to between 1 and 11 either with 1*N* HCl or 0.5*N* NaOH. The pH of each extract was rechecked after separation from the residue.

Tapped bulk density was measured by the method of Hanrahan and Konston (1965).

Water hydration capacity was determined by the method of Quinn and Paton (1979).

Oil absorption was measured by the method of Lin et al (1974). Oil emulsification value was determined by the method of Inklaar and Fortuin (1969). Mazola corn oil (Best Foods, Division of Canada Starch Co.) was used in both procedures.

Ability to be whipped and foam stability were determined by the method of Lin et al (1974) modified as follows: a 6-g sample in 200 ml of distilled water was whipped for 8 min in a Kitchen Aid food mixer at a speed setting of six. Longer whipping time or higher speed did not increase either foam volume or stability.

Whey protein nitrogen index was determined by the method of Leighton (1962). Hoffman-Dalby farinograms were prepared by AACC (1961) method 54-20, using a Brabender Farinograph model FA-MV100 equipped with a 300-g bowl at 30° C, with sigmoid blades rotating at 63 rpm. Additional farinograms were made with salted dough containing 6% NDM or PPCW by AACC (1957) method 26.3. Both constant flour weight and constant dough weight procedures were used.

Test baking was by the AACC (1961) straight dough method 10-85, using a 3-hr fermentation period. The dough formula consisted of 100 g of a commercial long patent flour (moisture, 14.0%; ash, 0.5%; and N, 2.5%) milled from Canadian hard red spring wheat, 2.5 g of fresh yeast (Fleischmann's, Standard Brands, Canada), 3 g of shortening (Crisco, Procter and Gamble, Canada), 5 g of sucrose, 2 g of NaCl, and 6 g of NDM or NDM substitute. In some instances more than 6 g of PPCW was incorporated into dough. In those cases the amount of flour was reduced by the amount of PPCW in excess of 6 g.

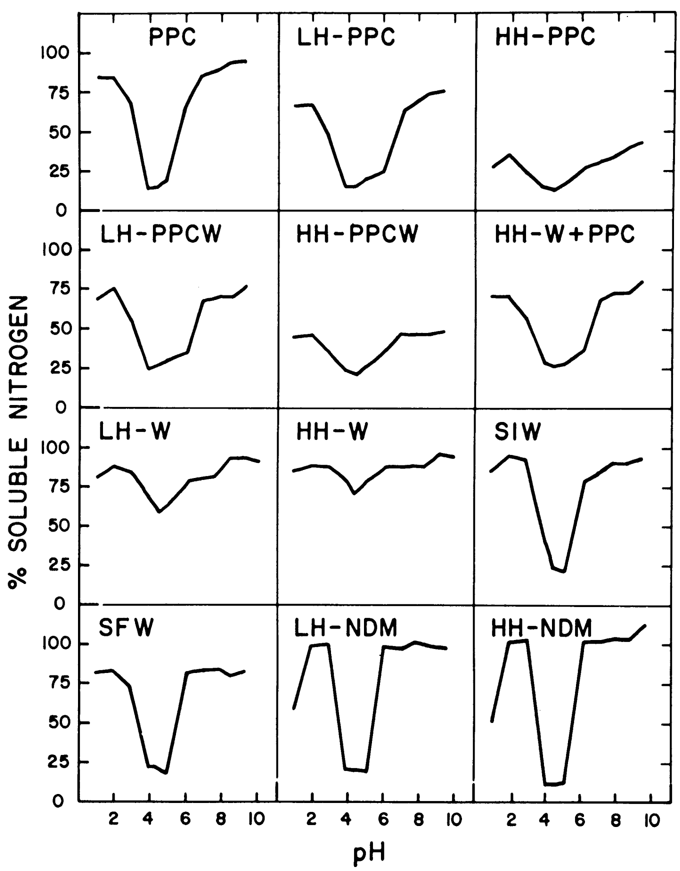


**Fig. 2.** Nitrogen solubility indices of pea protein concentrate (**PPC**)-cheese whey (**W**) blends (**PPCW**) and control samples. **LH** = treated with low heat, **HH** = treated with high heat, **SIW** = soy protein isolate-caseinate-whey blend, **SFW** = soy flour-sweet whey blend, **NDM** = nonfat dry milk.

**TABLE I**
**Composition (%) of Starting Materials, Blends, and Control Samples[a]**

| Sample[b] | Moisture | Protein[c] | Crude Fat[c] | Crude Fiber[c] | Ash[c] | Nitrogen-Free Extract[c] |
|---|---|---|---|---|---|---|
| Controls | | | | | | |
| LH-NDM | 5.8 | 39.3 | 0.0 | 0.0 | 8.2 | 52.5 |
| HH-NDM | 4.6 | 38.8 | 0.0 | 0.0 | 8.2 | 53.0 |
| PPC | 8.2 | 55.5 | 3.7 | 3.5 | 5.6 | 31.7 |
| LH-PPC | 2.4 | 53.2 | 1.2 | 3.5 | 6.8 | 35.3 |
| HH-PPC | 2.4 | 51.9 | 1.2 | 3.5 | 6.2 | 37.2 |
| W | 95.3 | 0.6 | ... | ... | ... | ... |
| LH-W | 3.4 | 13.0 | 0.0 | 0.0 | 9.3 | 77.7 |
| HH-W | 3.1 | 10.2 | 0.0 | 0.0 | 10.0 | 79.8 |
| SFW | 4.8 | 29.1 | 0.0 | 1.8 | 9.1 | 60.0 |
| SIW | 4.5 | 37.3 | 0.0 | 0.3 | 8.0 | 54.4 |
| Blends | | | | | | |
| LH-PPCW | 3.3 | 35.3 | 0.2 | 2.0 | 8.0 | 54.4 |
| HH-PPCW | 5.4 | 34.7 | 0.0 | 1.9 | 7.9 | 55.5 |
| HH-W+PPC | 4.1 | 32.6 | 0.0 | 2.0 | 9.2 | 56.2 |
| LSD ($P = 0.05$) | 0.2 | 0.4 | 0.0 | 0.2 | 0.2 | 0.6 |
| SEM | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.2 |

[a] Results are based on two or more replicates.
[b] LH = Treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPC = air-classified pea protein concentrate, W = sweet cheddar cheese whey, SFW = soy flour-whey blend, SIW = soy protein isolate-caseinate-whey blend, PPCW = pea protein concentrate-whey blend, HH-W+PPC = blend of HH-W and unheated PPC.
[c] Dry basis except for W. Percent protein is N × 6.25 except for NDM and W in which percent protein is N × 6.38.

One-pound loaves of bread containing 6% LH-PPCW were made by scaling up the above formula; these were evaluated for sensory quality by the randomized triangle test of Larmond (1977) in comparison with similar loaves containing equivalent amounts of either HH-NDM or SFW. A taste panel of 48 panelists tested sliced bread samples in two separate tests on different days. In each test the bread samples came from corresponding sections of the respective loaves. The samples were tested under red light so that color difference would not affect the panelists' judgment.

Crumb compressibility was measured with a Food Technology Corporation texturometer by the method of Fleming and Sosulski (1977). Each value reported was the average of measurement on four pieces (5 × 5 × 1.5 cm) of the crumb sample.

For statistical evaluation of the analytical data, variances of each method were pooled after being tested for homogeneity (Barlett's test) at $P \leq 0.05$ (Snedecor and Cochran 1967). The least significant difference test was used to demonstrate the significant differences between means.

## RESULTS AND DISCUSSION

### Preparation of PPCW Blends and Control Samples

The spray-dried PPCW blends and the PPC and W controls were free-flowing, light tan powders.

The PPCW blends were prepared without some of the difficulties that were encountered in processing W or PPC slurries separately. To prepare a dry whey product that is nonhygroscopic, a holding period before spray drying is recommended to induce lactose crystallization (Galsmar and Bergmann 1967). The addition of PPC and W eliminated the need for lactose crystallization. In the processing of PPC alone, the slurry became quite viscous during the evaporation step. If the solids content exceeded 30%, problems were encountered in pumping the slurry. The lower solids content required a lower feed rate to maintain the desired outlet air temperature of the dryer and thus required a longer drying time. Guy et al (1969) have reported similar observations in spray drying cheese whey-soy flour mixtures. No such difficulties were encountered in spray drying PPCW blends at a total solids content of 40%.

### Chemical Composition

The proximate compositions of the starting materials, PPCW blends, and control samples are shown in Table I. Protein content of the PPCW blends ranged between 32.6 and 35.3%. Crude fat and fiber content were fairly constant among PPCW blends. On heating and blending with W, lipid components in PPC apparently were converted to a form no longer extractable by ether.

The amino acid composition, chemical score, and essential amino acid index are shown in Table II. The sulfur-containing amino acids were first limiting in all samples. The PPCW blends were slightly low in lysine relative to starting materials, indicating some destruction during processing. The chemical scores of the blends were slightly better than those of the PPC and W samples given similar heat treatment but lower than those of the NDM controls.

### Functional Properties

Nitrogen solubility profiles are used increasingly as a guide to protein functionality (Kinsella 1976). The nitrogen solubility index curves for all the blends and control samples are shown in Fig. 2. Heat, particularly the HH treatment, reduced nitrogen solubility in the PPC controls but appeared to enhance that in the W controls. The curves for the PPCW blends closely approximated the empirical curves that represent the weighted average of the component materials, except that the observed nitrogen solubility above pH 7.0 may be lower than would be expected on that basis. Above pH 7.0, the blends were lower in nitrogen solubility than any of the other samples that had received similar heat treatment except for HH-PPC.

Results of other tests of functional properties are shown in Table III. The bulk densities of PPCW blends ranged from 0.66 to 0.86 g/ml and were similar to those of the NDM controls. The PPC

TABLE II
Essential Amino Acid Distribution

| Sample[a] | Amino Acids (g/16 g of N) Lys | Met + Cys | Try | Thr | Ile | Leu | Tyr + Phe | Val | Chemical Score | EAAI[b] |
|---|---|---|---|---|---|---|---|---|---|---|
| Controls | | | | | | | | | | |
| Reference Protein[c] | 5.5 | 3.5 | 1.0 | 4.0 | 4.0 | 7.0 | 6.0 | 5.0 | 100 | 100 |
| LH-NDM | 7.3 | 3.1 | 1.9 | 4.2 | 4.3 | 9.2 | 8.5 | 6.3 | 89 | 125 |
| HH-NDM | 7.7 | 2.9 | 2.0 | 4.2 | 4.1 | 9.0 | 9.1 | 5.4 | 83 | 123 |
| PPC | 7.4 | 2.3 | 1.2 | 3.9 | 4.3 | 7.1 | 8.5 | 5.0 | 66 | 106 |
| LH-PPC | 7.3 | 2.8 | 1.3 | 3.9 | 4.0 | 7.3 | 8.0 | 4.8 | 80 | 108 |
| HH-PPC | 7.0 | 2.6 | 1.4 | 3.9 | 4.1 | 7.3 | 8.3 | 4.7 | 74 | 108 |
| W | 9.0 | 3.0 | 1.9 | 7.3 | 5.7 | 8.5 | 5.6 | 5.3 | 86 | 130 |
| LH-W | 7.3 | 2.4 | 1.6 | 6.4 | 5.3 | 7.9 | 6.5 | 5.2 | 69 | 119 |
| HH-W | 6.3 | 2.4 | 1.3 | 7.5 | 6.0 | 8.5 | 5.9 | 5.7 | 69 | 119 |
| SFW | 6.6 | 2.9 | 1.5 | 4.9 | 4.7 | 8.3 | 8.0 | 5.0 | 83 | 117 |
| SIW | 6.2 | 2.8 | 1.8 | 4.5 | 4.8 | 8.7 | 8.7 | 5.6 | 80 | 120 |
| Blends | | | | | | | | | | |
| LH-PPCW | 6.3 | 2.8 | 1.1 | 4.4 | 4.4 | 7.6 | 8.0 | 5.0 | 80 | 107 |
| HH-PPCW | 6.6 | 3.0 | 1.2 | 4.3 | 4.4 | 7.8 | 8.3 | 5.1 | 86 | 111 |
| HH-W+PPC | 6.5 | 2.9 | 1.3 | 4.5 | 4.4 | 7.6 | 8.0 | 5.0 | 83 | 111 |
| SD[d] | 0.2 | 0.4 | 0.3 | 0.1 | 0.3 | 0.2 | 0.4 | 0.1 | ··· | ··· |

[a] LH = Treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPC = air-classified pea protein concentrate, W = sweet cheddar cheese whey, SFW = soy flour-whey blend, SIW = soy protein isolate-caseinate-whey blend, PPCW = pea protein concentrate-whey blend, HH-W+PPC = blend of HH-W and unheated PPC.
[b] Essential Amino Acid Index.
[c] FAO (1973).
[d] n = 26.

TABLE III
Functional Properties of Pea Protein Concentrate-Cheese Whey Blends and Control Samples[a]

| Sample[b] | Tapped Bulk Density (g/ml) | pH of 10% Dispersion | WHC[c] (%, v/w) | Oil Absorption (%, v/w) | Emulsification (%, v/v) |
|---|---|---|---|---|---|
| Controls | | | | | |
| LH-NDM | 0.69 | 6.7 | 85 ± 6 | 110 | 25.6 |
| HH-NDM | 0.76 | 6.7 | 113 ± 7 | 93 | 14.7 |
| PPC | 0.45 | 6.4 | 153 ± 4 | 113 | 22.4 |
| LH-PPC | 0.43 | 7.5 | 210 ± 5 | 183 | 15.9 |
| HH-PPC | 0.42 | 6.7 | 250 ± 6 | 153 | 6.4 |
| LH-W | 0.82 | 6.3 | 60 ± 5 | 87 | 10.1 |
| HH-W | 0.88 | 6.3 | 40 ± 5 | 77 | 11.9 |
| SFW | 0.71 | 7.2 | 131 ± 7 | 100 | 17.3 |
| SIW | 0.81 | 6.5 | 102 ± 7 | 77 | 6.0 |
| Blends | | | | | |
| LH-PPCW | 0.66 | 6.7 | 143 ± 8 | 243 | 25.2 |
| HH-PPCW | 0.86 | 6.7 | 153 ± 7 | 73 | 16.3 |
| HH-W+PPC | 0.73 | 6.8 | 113 ± 6 | 107 | 19.6 |
| LSD ($P = 0.05$) | .01 | ··· | ··· | 9 | 1.2 |
| SEM | .003 | ··· | ··· | 3 | 0.4 |

[a]Results are based on two or more replicates, dry basis.
[b]LH = Treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPC = air-classified pea protein concentrate, W = sweet cheddar cheese whey, SFW = soy flour-whey blend, SIW = soy protein isolate-caseinate-whey blend, PPCW = pea protein concentrate-whey blend, HH-W+PPC = blend of HH-W and unheated PPC.
[c]Water hydration capacity ± ½ the range (Quinn and Paton 1979).

TABLE IV
Volume Increase from Whipping and Foam Stability of Pea Protein Concentrate-Cheese Whey Blends and Control Samples[a]

| Sample[b] | Protein Concentration[c] (%) | Volume Increase on Whipping (%) | Relative Foam Volume[d] After Elapsed Time (min) 10 | 30 | 60 | 120 |
|---|---|---|---|---|---|---|
| Controls | | | | | | |
| LH-NDM | 1.2 | 557 | 97 | 8 | 0 | 0 |
| HH-NDM | 1.2 | 474 | 94 | 0 | 0 | 0 |
| PPC | 1.7 | 469 | 84 | 3 | 0 | 0 |
| LH-PPC | 1.6 | 383 | 80 | 24 | 5 | 5 |
| HH-PPC | 1.6 | 542 | 95 | 88 | 17 | 2 |
| LH-W | 0.4 | 150 | 0 | 0 | 0 | 0 |
| HH-W | 0.3 | 86 | 0 | 0 | 0 | 0 |
| SFW | 0.9 | 148 | 0 | 0 | 0 | 0 |
| SIW | 1.1 | 581 | 94 | 0 | 0 | 0 |
| Blends | | | | | | |
| LH-PPCW | 1.0 | 405 | 94 | 85 | 79 | 69 |
| HH-PPCW | 1.0 | 385 | 89 | 70 | 52 | 3 |
| HH-W+PPC | 1.0 | 415 | 94 | 85 | 77 | 69 |
| LSD ($P = 0.05$) | 0.4 | 11 | 3 | 3 | 4 | 1 |
| SEM | 0.1 | 4 | 1 | 1 | 1 | 1 |

[a]Results are based on two replicates, dry basis.
[b]LH = Treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPC = air-classified pea protein concentrate, W = sweet cheddar cheese whey, SFW = soy flour-whey blend, SIW = soy protein isolate-caseinate-whey blend, PPCW = pea protein concentrate-whey blend, HH-W+PPC = blend of HH-W and unheated PPC.
[c]Grams of protein per 100 ml of sample slurry in water.
[d]Foam volume at given elapsed time as percentage of foam volume 1 min after whipping.

controls had a relatively low bulk density.

The pH of 10% dispersion was very close to 6.7 except for PPC, LH-W, and HH-W, which were slightly lower, and LH-PPC and SFW, which were slightly higher.

PPC showed the highest water hydration capacity, a property enhanced by the heat treatment. The PPCW blends were intermediate in water hydration capacity relative to the two separate components and in general higher than the two NDM. Factors influencing water hydration capacity have been discussed by Briskey (1970).

Oil absorption data are noteworthy in that HH-PPCW is much lower whereas LH-PPCW is considerably higher than would be expected on the basis of the data for the individual components.

Heat reduced the oil emulsification capacity of PPC but affected that of the PPCW blends less. Oil emulsification values for the blends were similar to those of the two NDM.

All samples except W and SFW produced substantial amounts of foam (Table IV). All samples containing PPC had light yellow foam. The foams of the PPCW blends were the most stable among all the samples tested. Foam formation has been discussed by Briskey (1970) and by DeVilbiss et al (1974).

Our data on functional properties of the PPC are in general agreement with those reported by Sosulski et al (1976) and Fan and Sosulski (1974). The functional properties of PPCW blends are comparable to the data reported by Thompson (1977, 1978) for coprecipitates of whey proteins with rapeseed, soybean, or cottonseed proteins.

The Hoffman-Dalby farinograph test and the whey protein

TABLE V
Hoffman-Dalby Farinograph Absorption and Whey Protein Nitrogen Index for Pea Protein Concentrate-Cheese Whey Blends and Control Samples[a]

| Samples[b] | Farinogram Characteristics: Percent Absorption (Flour + Sample) | Percent Absorption Sample[c] | Arrival Time[d] (min) | WPNI[e] |
|---|---|---|---|---|
| Wheat Flour 'as is' | 70.2 | ··· | 1.8 | ··· |
| Controls | | | | |
| LH-NDM | < 55.1[f] | < 40.0 | ···[g] | 6.9 |
| HH-NDM | 64.1[f] | 52.5 | 31.5 | 0.9 |
| LH-PPC | 87.6[h] | 139.8 | 6.0 | ··· |
| HH-PPC | 97.3[h] | 178.4 | 3.0 | ··· |
| LH-W | < 57.7[h] | < 20.0 | ···[g] | 3.6 |
| HH-W | < 57.7[h] | < 20.0 | ···[g] | 2.3 |
| SFW | 58.4[f] | 46.5 | 32.5 | ··· |
| SIW | 57.7[f] | 45.3 | 45.0 | ··· |
| Blends | | | | |
| LH-PPCW | 60.5[f] | 50.8 | 23.0 | ··· |
| HH-PPCW | 81.1[f] | 92.0 | 12.0 | ··· |
| HH-W+PPC | 63.8[f] | 57.4 | 21.0 | ··· |
| LSD ($P = 0.05$) | 0.9 | 2.7 | 0.3 | 0.2 |
| SEM | 0.3 | 1.0 | 0.1 | 0.1 |

[a]Results are based on two or more replicates.
[b]LH = Treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPC = air-classified pea protein concentrate, W = sweet cheddar cheese whey, SFW = soy flour-whey blend, SIW = soy protein isolate-caseinate-whey blend, PPCW = pea protein concentrate-whey blend, HH-W+PPC = blend of HH-W and unheated PPC.
[c]Percent absorption was calculated from percent absorption of flour plus sample (AACC method 54-20, 1961).
[d]For these farinograms, the total quantity of water was added within 30 sec after 0-min time of farinogram.
[e]Whey protein nitrogen index, dry basis (Leighton 1962), expressed as milligrams of N per gram of sample.
[f]Flour/sample ratio, 1:1 by weight.
[g]Curve never reached 500 BU.
[h]Flour/sample ratio, 3:1 by weight.

nitrogen index test are both designed to evaluate the quality of NDM for use in baking. The NDM for use in bread is prepared by a high temperature process. Without the HH treatment, deleterious effects including lowered water absorption and a longer dough mixing requirement have been observed (Larsen et al 1949). By the current standards of AACC method 54-20 (1961) and the American Dry Milk Institute (Anonymous 1971), the HH-NDM was of good quality for use in bread whereas the LH-NDM was not (Table V). The conclusions from the Hoffman-Dalby test as applied to the other samples were: spray-dried W alone, regardless of heat treatment, contributed to reduced water absorption and retarded dough development. LH-PPC and HH-PPC resulted in higher water absorption. The effect was greater for the latter, agreeing with the results of Jeffers et al (1978). In the PPCW blends, the balance of these opposing effects gave absorption properties as good as that of HH-NDM and better than those of either soy-whey blend. The blends did retard arrival time, but to a lesser extent than either HH-NDM or the soy-whey blends did.

Skovholt and Baily (1932) have pointed out that measurement of the effect of NDM on water absorption, using the farinograph, is more appropriately done with dough containing added salt. Farinograms of doughs containing 6% of either NDM of PPCW

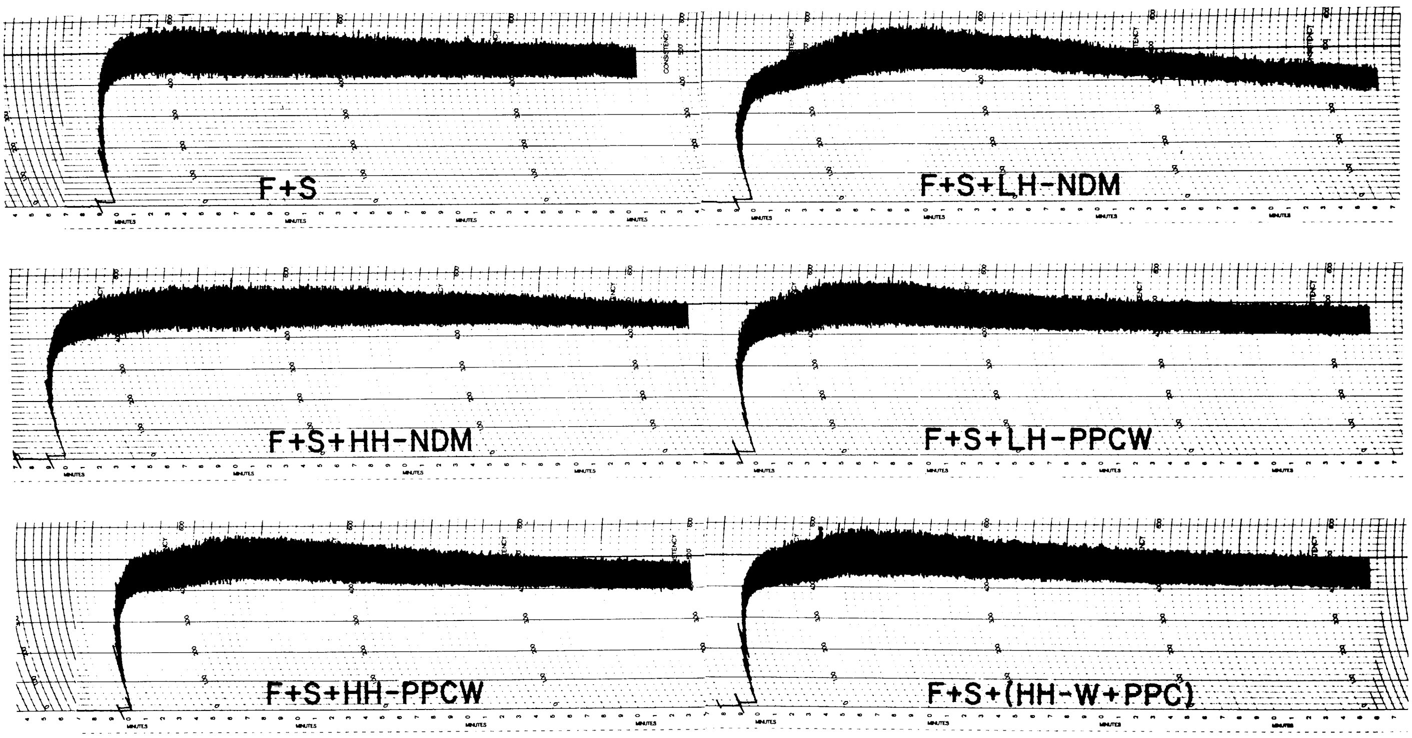


**Fig. 3.** Farinograms as affected by pea protein concentrate (**PPC**)-cheese whey (**W**) blends (**PPCW**) and control samples incorporated at the 6% level in doughs containing 2% salt (constant dough weight method). **F** = flour, **S** = salt, **LH** = treated with low heat, **HH** = treated with high heat, **NDM** = nonfat dry milk.

**TABLE VI**
**Farinogram Characteristics of Pea Protein Concentrate-Cheese Whey Blends at 6% Level with Baker's Grade Hard Red Spring Wheat Flour and 2% Salt[a]**

| Ingredients[b] | Method | Percent Absorption | Arrival Time (min) | Peak Time (min) | Stability (min) | BU: MTI[c] | BU: 25-min Drop |
|---|---|---|---|---|---|---|---|
| Controls | | | | | | | |
| F | CW[d] | 64.8 | 1.5 | 4.0 | 18.5 | 10 | ··· |
| F+S | CW | 62.4 | 2.0 | 6.0 | > 18.0 | 10 | ··· |
| | CD[e] | 61.7 | 1.5 | 6.0 | > 29.5 | 10 | 15 |
| F+S+LH-NDM | CW | 69.5 | 7.0 | 12.0 | 16.0 | 20 | 100 |
| | CD | 66.8 | 5.5 | 11.5 | 17.0 | 20 | 90 |
| F+S+HH-NDM | CW | 68.7 | 6.0 | 14.5 | 33.5 | 10 | 20 |
| | CD | 66.5 | 3.0 | 11.0 | 35.5 | 5 | 20 |
| Blends | | | | | | | |
| F+S+LH-PPCW | CW | 67.8 | 4.5 | 9.0 | 22.5 | 15 | 50 |
| | CD | 65.9 | 2.5 | 8.5 | 25.0 | 20 | 50 |
| F+S+HH-PPCW | CW | 70.3 | 4.0 | 9.5 | 24.0 | 15 | 60 |
| | CD | 68.0 | 2.0 | 9.5 | 25.0 | 10 | 60 |
| F+S+HH-W+PPC | CW | 68.3 | 4.0 | 9.5 | 28.0 | 20 | 55 |
| | CD | 66.0 | 2.5 | 9.0 | 30.5 | 20 | 45 |

[a] Results are based on two replicates; standard deviation, < 1.
[b] F = Flour, S = salt, LH = treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPCW = air-classified pea protein concentrate-cheese whey blend, HH-W+PPC = blend of high heat whey and unheated pea protein concentrate.
[c] Mixing tolerance index.
[d] Constant flour weight (14% mb), method 26.3 (AACC 1957).
[e] Constant dough weight (480 g), method 26.3 (AACC 1957).

blend and 2% added salt are shown in Fig. 3 and the corresponding data in Table VI. Salt at this level decreased water absorption, whereas it increased dough stability. Under these conditions, both HH-NDM and LH-NDM increased water absorption by similar amounts. The PPCW blends also increased absorption. The two NDM, and to a lesser extent the PPCW blends, retarded arrival times and increased peak times. This is similar to the observations of Aidoo (1972) for dough supplemented with soy flour. The PPCW blends showed a greater 25-min drop-off than HH-NDM did but not as great as LH-NDM did. However, none of these supplements had a great effect on the inherent dough characteristics of the flour.

**TABLE VII**
**Baking Quality of Pea Protein Concentrate-Cheese Whey Blends and Control Samples[a]**

| Sample[b] | Water Absorption (%) | Specific Loaf Volume (cc/g) | Quality Score[c] | Crumb Compressibility (lb force) |
|---|---|---|---|---|
| Controls | | | | |
| Flour | 65.2 | 5.78 | 101 | 41 |
| LH-NDM | 65.2 | 6.42 | 120 | 30 |
| HH-NDM | 65.2 | 6.42 | 119 | 29 |
| PPC | 64.2 | 6.30 | 117 | 46 |
| LH-PPC | 65.2 | 5.70 | 102 | 49 |
| HH-PPC | 66.2 | 5.04 | 89 | 59 |
| LH-W | 64.0 | 5.45 | 99 | 45 |
| HH-W | 63.6 | 5.53 | 100 | 43 |
| SFW | 63.4 | 5.99 | 112 | 45 |
| SIW | 63.5 | 6.11 | 115 | 43 |
| Blends | | | | |
| LH-PPCW | 65.2 | 6.17 | 118 | 34 |
| LH-PPCW (10%) | 62.8 | 6.04 | 112 | 52 |
| LH-PPCW (15%) | 58.8 | 5.23 | 96 | 62 |
| HH-PPCW | 65.2 | 5.78 | 106 | 40 |
| HH-W+PPC | 65.2 | 6.04 | 114 | 36 |
| LSD ($P = 0.05$) | 0.2 | 0.21 | 4 | 5 |
| SEM | 0.1 | 0.1 | 1 | 2 |

[a] Results are based on six replicates except for crumb compressibility results, which are based on four replicates.
[b] LH = Treated with low heat, HH = treated with high heat, NDM = nonfat dry milk, PPC = air-classified pea protein concentrate, W = sweet cheddar cheese whey, SFW = soy flour-whey blend, SIW = soy protein isolate-caseinate-whey blend, PPCW = pea protein concentrate-whey blend, HH-W+PPC = blend of HH-W and unheated PPC. Sample was added to bread at 6% by weight of flour except as noted. The amount in excess of 6% replaced an equivalent amount of wheat flour.
[c] Quality score was calculated as described in AACC method 10-85 (1961).

**TABLE VIII**
**Sensory Evaluation by Triangle Test[a] of Bread Supplemented with Pea Protein Concentrate-Cheese Whey Blend**

| Number of Panelists | Bread Supplemented with LH-PPCW[b] vs HH-NDM[b] | SFW[b] |
|---|---|---|
| Identifying odd sample correctly | 17[c] | 18[c] |
| Identifying odd sample incorrectly | 29 | 30 |
| With no answer | 2 | 0 |
| Total | 48 | 48 |
| With correct identification who showed preference for bread containing | | |
| LH-PPCW[b] | 9 | 9 |
| HH-NDM[b] | 8 | ... |
| SFW[b] | ... | 9 |
| Total | 17 | 18 |

[a] One-pound loaves were baked for sensory evaluation. Each supplement was incorporated at 6% level.
[b] LH-PPCW = Pea protein concentrate-whey blend treated with low heat, HH-NDM = nonfat dry milk treated with high heat, SFW = soy flour-whey blend.
[c] Twenty-three correct responses were needed for the differences to be significant at 5% confidence interval.

## Baking Quality

The results of baking tests are shown in Table VII and Fig. 4. Bread containing LH-PPCW at the 6% level was similar in quality to bread containing an equal amount of NDM. This similarity included the effect of the additive on crust color (Bertram 1953). Bread samples containing 6% LH-PPCW scored slightly higher than did the corresponding samples supplemented with either of the two commercial soy-whey blends. The HH treatment of PPCW depressed loaf volume. A similar volume-depressing effect was observed in bread supplemented with HH-PPC, indicating that PPC was the component suffering most of the adverse effects. Increasing the level of LH-PPCW above 6% decreased loaf volume, and an increasingly dull-yellow crumb color was evident.

In contrast to the results of Larsen et al (1949) and Larson et al (1951), we did not detect any deleterious effects of our LH-NDM sample on baking properties. Supplementation with either LH-NDM or HH-NDM at 6% improved loaf characteristics relative to the unsupplemented controls. The improving effect of HH-NDM was not significantly better than that of LH-NDM. The effect of NDM on bread has been reconsidered recently by Ling et al (1976, 1977).

Both LH-W and HH-W at the 6% level decreased loaf volumes considerably. Similar results on W-supplemented breads were reported by Volpe and Zabik (1975) and by Guy (1973).

Of the various additives, PPC, W, the soy-whey blends, and levels of PPCW greater than 6% all reduced water absorption. Conflicting data on the effect of PPC on water absorption have been reported (Anonymous 1974, Fleming and Sosulski 1977).

Crumb compressibility measurement indicated that the softening effect of the LH-PPCW blend was nearly equivalent to that of HH-NDM at the 6% level of supplementation but that higher levels of PPCW increased crumb firmness. The blend had a considerably greater capacity to impart softness to the crumb than did either of the two individual components.

The use of dough conditioners has been recommended for breads supplemented with vegetable protein concentrates (Thompson 1977), although Fleming and Sosulski (1977) found the beneficial effect to be small unless the level of protein supplement exceeded 10%. Our results indicated that dough conditioners were not essential when LH-PPCW was used as a replacement for NDM as long as the supplementation level did not exceed 6%.

## Sensory Evaluation

Test panelists were not able to distinguish LH-PPCW bread from HH-NDM bread at a statistically significant level (Table

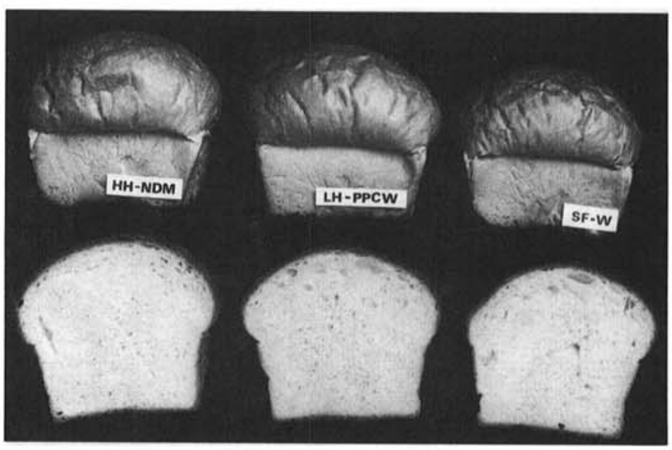

**Fig. 4.** Comparison of 100-g loaves (sliced lengthwise) supplemented at the 6% level with low heat pea protein concentrate-cheese whey blend (**LH-PPCW**), with high heat nonfat dry milk (**HH-NDM**), and with a commercial soy flour-whey blend (**SFW**).

VIII). Approximately 60% of the panelists incorrectly identified the odd sample in the triangle test. Among the panelists who correctly identified the odd sample, all indicated the differences to be slight, and the numbers indicating a preference for either LH-PPCW bread or HH-NDM bread were approximately equal. The panelists comparing LH-PPCW and SFW breads showed a similar inability to distinguish differences and a lack of any clear-cut preference.

## CONCLUSIONS

Coprocessing of PPC and W greatly reduced the problem of high viscosity that was encountered in processing the PPC separately. The need for lactose crystallization in W before spray drying was eliminated in the PPCW blends. The results indicate that PPCW blends do have potential as replacement for NDM in bread. Comparison of LH-PPCW to HH-PPCW indicated no advantages of the HH treatment in the process. In fact, detrimental effects on baking quality were associated with the heating of the PPC component. Comparison of LH-PPCW to HH-W+PPC indicated that the HH treatment of W alone did not improve the baking quality of HH-W+PPC. Rather, a slightly lower baking quality was noticed.

Studies to further evaluate this type of product appear to be warranted. Data are needed on the effects of PPCW blends when included in bread made of flours that represent a wide range of baking quality.

Among all the blends, LH-PPCW was superior in functionality. Functional properties of the LH-PPCW suggest that it may have additional food uses in products such as pasta, meat patties, egg white substitutes, and frankfurters and as an extender for milk supplies.


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