Effect of Heat-Moisture Treatment of Field Bean (*Phaseolus vulgaris*) Flour and Protein Isolate on Water Uptake

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ABSTRACT

Bean flour or protein isolates, equilibrated to moisture contents between 14 and 40%, were heated at either 70 or 90° C for various times. At every moisture content, the hydration capacity of bean flour increased with the time of heat treatment; increasing the moisture content increased the hydration capacity of the flour. The rate of water uptake of flour was increased by almost all heat-moisture treatments. The hydration capacity of bean protein isolate was reduced by heat-moisture treatments; extensive losses and hydration capacity occurred with increasing temperature and moisture content. The effect of heat-moisture treatments on the rate of water uptake of bean protein was not as pronounced as for bean flour.

Legumes serve as the main source of protein in many parts of the world. Dry bean (*Phaseolus vulgaris*) contains over 20% protein and complements cereals in terms of amino acid balance because of its relatively high amounts of lysine. Beans also serve as an important source of several essential minerals and vitamins.

In previous publications (Pilosof et al 1982a,b), the effect of specific heat-moisture treatments on water sorption isotherms and nitrogen solubility of bean flour and protein isolates was studied. Some nutritional properties such as available lysine and trypsin inhibitory activity of bean flour as affected by heat-moisture treatments were also investigated (Buera et al 1983, 1984).

Water uptake by imbibition is an important functional property in foods such as sausages, custards, and doughs. The uptake of water (Hermansson 1972) can be measured using a method developed by Baumann (1966). In a previous publication (Pilosof et al 1985), this method was applied to study the kinetics of water uptake by several food powders and the uptake of water was described mathematically.

We present here a study on the effect of heat-moisture treatment of bean flour and protein isolate on water uptake.

MATERIALS AND METHODS

Raw Materials

White field beans (*Phaseolus vulgaris* var. Alubia) purchased at a local market were ground to an 80-mesh size. The proximate composition of bean flour was 12.3% moisture, 20.7% protein, and 44.8% starch.

Bean protein isolate was obtained by extraction with water and dilute NaOH as described previously (Pilosof et al 1982a). The proximate composition of protein isolate was 4.8% moisture, 83.9% protein, and 0.7% starch.

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Analytical Methods

Protein (N × 6.25) was analyzed by the macro-Kjeldahl method. Starch was determined as glucose after acid hydrolysis of samples subjected previously to sugar extraction (AOAC 1980). Moisture content was determined gravimetrically by placing the samples in an oven at 110° C for 1–3 hr until a constant weight was reached.

Heat-Moisture Treatments

Different moisture levels (14, 30, 38, or 40% db) of flour or isolate were obtained by adding water directly; flour or isolate was spread in a thin layer and sprayed with water. The moistened sample was sealed in plastic pouches, placed in a refrigerator, and allowed to equilibrate for four days. The moisture-equilibrated sample was then transferred to sealed cans, placed in a temperature-controlled oven (±1° C), and heated at 70 and 90° C. Samples were removed from the oven at different times and freeze-dried before determining the water uptake.

Water Uptake

Water uptake of dry powders of flour or isolate was determined using the device proposed by Torgersen and Toledo (1977). At least two replicate experiments were run simultaneously at room temperature. Sample readings were taken every minute and were corrected for evaporation losses.

Kinetics of Water Uptake

In order to describe mathematically the curves of water uptake, the following empirical equation (Pilosof et al 1985) was used:

$$q = Qt / B + t, \tag{1}$$

where q is the amount of water taken up at time t; Q is the hydration capacity (maximum amount of water taken up), and B is the time needed to absorb half the maximum amount of water ($Q/2$). A program for nonlinear least squares analysis (Ralston and Jennrich 1978) was used to obtain parameters Q and B.

In earlier work (Pilosof et al 1985), the kinetics of water uptake was described by the following expression,

$$dq/dt = (BQ)^{-1}(Q-q)^2, \tag{2}$$

where $(BQ)^{-1}$ represents the specific rate constant K,

$$K = (BQ)^{-1}. \quad (3)$$

Standard deviations of Q, B, and K were calculated (Pilosof et al 1985).

RESULTS AND DISCUSSION

The uptake of water by bean flour and protein isolate was affected by heat treatment at 30% moisture content (Figs. 1 and 2). An equilibrium water uptake referred to as the hydration capacity (Q) was attained for flour and protein isolate at every heating time. The time needed to reach the equilibrium condition was reduced by heat treatment.

Heat treatment of bean protein isolate at 14, 30, and 40% moisture content resulted in a reduced hydration capacity (Fig. 3). The major reduction occurred during the first hour of heat treatment. Extensive losses of the hydration capacity occurred with increasing temperature and moisture content of protein isolate. However, only small differences were observed between 30 and 40% moisture content.

The loss of hydration capacity of bean protein isolate by heat treatment at higher moisture contents may result from the dual effects of protein denaturation and protein aggregation or cross-linking. Pilosof et al (1982a) showed that heat treatment of higher moisture content bean protein isolated reduces nitrogen solubility.

The specific rate constants (K) of water uptake by bean protein isolate as affected by heat-moisture treatment at 70° C and the statistical parameters Q and B that gave the best fit of experimental data are shown in Table I. Heat-moisture treatments increased rates of water uptake by decreasing either Q or B values. Similar results were obtained when protein isolates were heated at 90° C.

At every moisture content, the hydration capacity (Q) of bean flour increased with the time of heat treatment (Fig. 4). Increasing the moisture content increased the hydration capacity of the flour.

The loss of crystallinity in the starch component affects the hydration capacity of the flour and depends on the level of available water during heating. Hellman et al (1954) observed that heating wheat starch at water contents greater than 29% resulted in greater loss of crystallinity. Kulp and Lorenz (1981) observed that heat-moisture treatments (18–27% moisture content) increased the water-binding capacity and susceptibility to enzymatic attack of wheat and potato starch. The starch fraction of white beans contains approximately 30% amylose and shows slow swelling

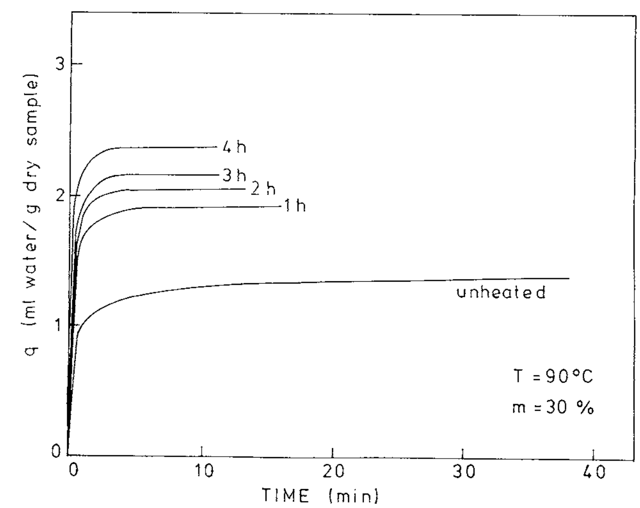

Fig. 1. Water uptake by bean flour (30% moisture) heat treated (90° C) for 0, 1, 2, 3, and 4 hr.

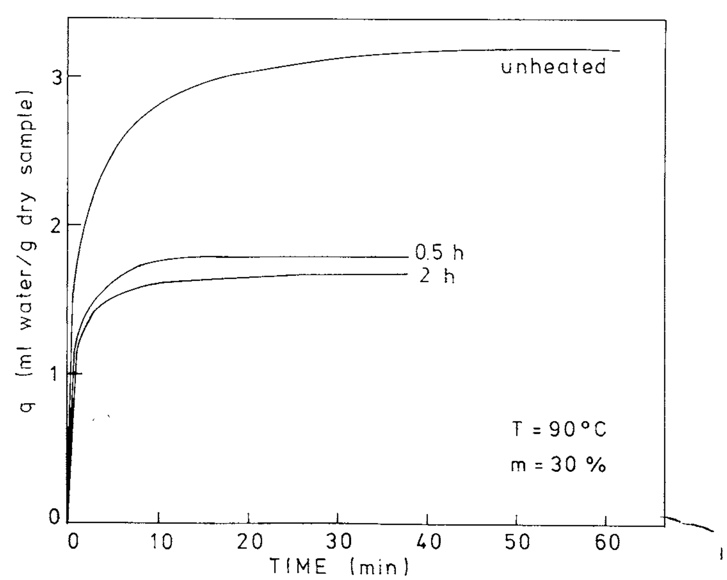

Fig. 2. Water uptake by bean protein isolate (30% moisture) heat treated (90° C) for 0, 0.5, and 2 hr.

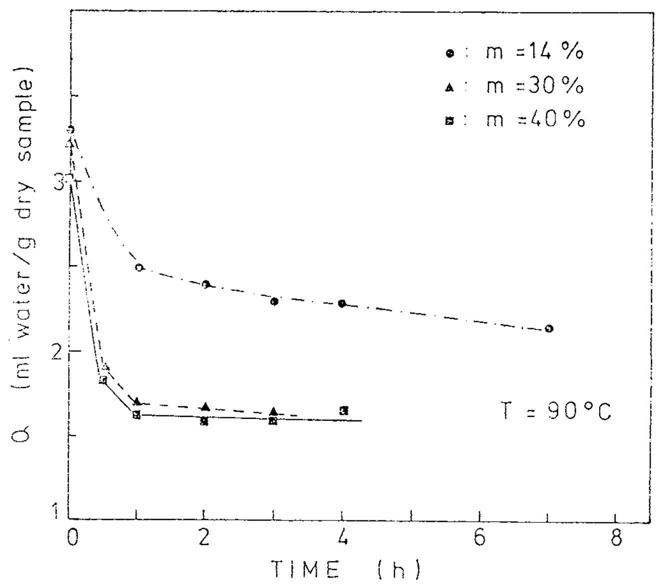

Fig. 3. Effect of the duration of heat treatment (90°) on the hydration capacity (Q) of bean protein isolate at different moisture contents (m).

TABLE I
Effect of Heat Treatment (70° C) of Bean Protein Isolate at 14, 30, and 40% Moisture Contents on Mathematical Parameters of Water Uptake

Moisture Content ($g\ H_2O/100\ g$ dry matter)	Time of Heat Treatment (hr)	Q[a] ($g\ H_2O/g$ dry matter)	B[b] (min)	K[c] (g dry matter/ min·g H_2O)
14	0	3.30	1.05	0.29 ± 0.005
	2	2.70	0.62	0.59 ± 0.02
	3	2.76	0.74	0.49 ± 0.01
	7	2.64	0.66	0.57 ± 0.02
	15.5	2.52	0.69	0.58 ± 0.02
30	0	3.22	1.28	0.24 ± 0.01
	1	1.99	0.75	0.68 ± 0.04
	2	1.61	0.62	1.00 ± 0.1
	3	1.75	0.53	1.07 ± 0.09
	4	1.65	0.45	1.35 ± 0.06
40	0	3.00	1.31	0.25 ± 0.01
	1	1.78	0.48	1.16 ± 0.07
	2	1.67	0.44	1.36 ± 0.08
	3	1.61	0.49	1.30 ± 0.1

[a] Hydration capacity (maximum amount of water taken up).
[b] Time required to absorb half the maximum amount of water.
[c] Specific rate constants and standard deviation.

TABLE II

Effect of Heat Treatment (70° C) of Bean Flour at 14, 30, and 38% Moisture Contents on Mathematical Parameters of Water Uptake

Moisture Content ($g H_2O/100 g$ dry matter)	Time of Heat Treatment (hr)	Q^a ($g H_2O/g$ dry matter)	B^b (min)	K^c (g dry matter/ min·g H_2)
14	0	1.40	1.50	0.47 ± 0.05
	3	1.60	2.23	0.28 ± 0.02
	6	1.66	1.38	0.44 ± 0.03
	12	1.67	1.42	0.42 ± 0.04
	24	1.73	0.31	1.80 ± 0.2
	36	1.87	0.25	2.10 ± 0.01
	48.5	2.06	0.054	9.00 ± 0.8
30	0	1.37	0.38	1.90 ± 0.2
	3	1.73	0.12	4.86 ± 0.08
	6	2.08	0.092	5.20 ± 0.2
	16	2.28	0.091	4.80 ± 0.2
	24	2.33	0.074	5.86 ± 0.02
	40	2.28	0.074	5.92 ± 0.08
38	0	1.50	0.079	8.30 ± 1.0
	3	2.26	0.061	7.30 ± 0.4
	7	2.34	0.079	5.40 ± 0.3

[a] Hydration capacity (maximum amount of water taken up).
[b] Time required to absorb half the maximum amount of water.
[c] Specific rate constants and standard deviation.

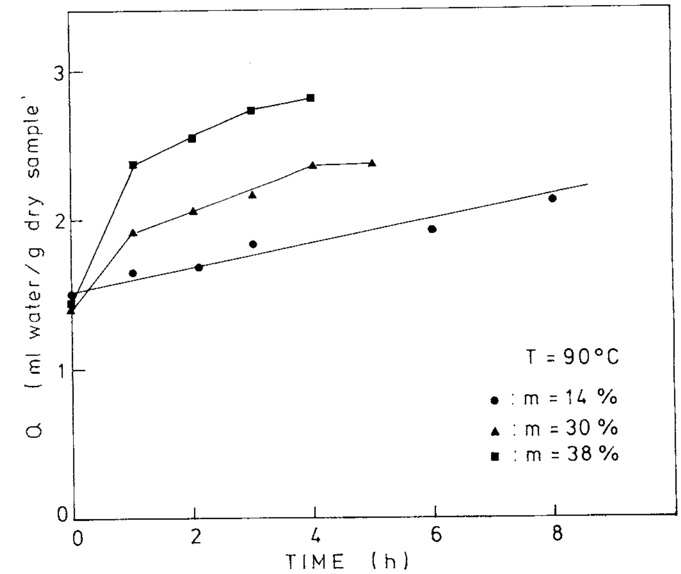

Fig. 4. Effect of the duration of heat treatment (90° C) on the hydration capacity (Q) of bean flour at different moisture contents (m).

(Sahasrabudhe et al 1981). Hydrogen bonding forces pull the amylose chains together into associated crystalline bundles leading to structures relatively resistant to swelling. Heat-moisture treatment likely leads to a loss of crystallinity of bean flour starch that improves its hydration capacity by exposing more binding sites to water.

Rate constants of water uptake of heat-moisture treated flours are shown in Table II together with Q and B values. At 14 and 30% moisture content, increasing times of heat treatment increased the rate constant of water uptake. However, at 38% moisture content, heat treatment resulted in a decrease of the rate constant. Similar trends were observed when bean flour was subjected to thermal treatment at 90° C.

The effect of heat-moisture treatments on the rate of water uptake was more pronounced for flour than for protein isolate. Flour and protein isolate also differed with respect to the effect of moisture equilibration with no heat treatment on the parameter B and on the rate constant. As shown in Tables I and II, moisture equilibration did not modify Q and B values for protein isolates and, therefore, K values were not affected. However, whereas moisture equilibration of flours did not modify Q values, it led to a marked decrease in B values with increasing moisture content, therefore increasing rate constants. Changes observed in the water uptake properties of bean protein isolate indicate that heat-moisture treatment during processing and storage must be minimized in order to preserve the hydration capacity of protein.

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