Food Chemistry, Vol. 58, No. 1–2, pp. 59–68, 1997

0308-8146/97 $17.00+0.00

ELSEVIER

PII: S0308-8146(96)00212-9

Effect of processing methods on nutrients and anti-nutritional factors in cowpea

N. Wang,[a]* M. J. Lewis,[a] J. G. Brennan[a] & A. Westby[b]

[a]*Department of Food Science and Technology, University of Reading, Whiteknights, Reading RG6 6AP, U.K.*
[b]*Natural Resources Institute, Central Avenue, Chatham Maritime, Chatham, Kent ME4 4TB, U.K.*

(Received 10 March 1995; revised version received 9 May 1996; accepted 9 May 1996)

The combined effects of soaking, water and steam blanching on the nutrients, oligosaccharides and trypsin inhibitor activity (TIA) in cowpea were investigated. The combination of soaking and steam-blanching had less effect on losses of nutrients than did soaking and water-blanching. Steam blanching resulted in higher reduction in TIA than water blanching. However, water blanching reduced more oligosaccharides in cowpea than steam blanching did. The effect of soaking on starch gelatinization was not significant during water-blanching. However, the influence of soaking on starch gelatinization was significant when it was combined with steam-blanching. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Cowpeas are extensively grown in many countries throughout the world since they are an important source of vegetable protein. Utilization of vegetable protein is gaining increasing attention due to the world need for more low-cost dietary proteins, particularly for low income countries. The high cost and limited availability of animal proteins in the developing countries have directed interest towards several seed and legume proteins as potential sources of vegetable protein for food use (Sathe & Salunkhe, 1981). However, besides the nutritional components, cowpeas contain amounts of anti-nutritional factors which have to be removed or eliminated to improve their nutritional quality and organoleptic acceptability. Factors such as trypsin inhibitors, which reduce nutritional quality of the protein, are relatively heat-labile and adequate heat treatment has been found to overcome them (Rackis, 1966). A wide range of low cost appropriate processing methods, such as boiling (Jood *et al.*, 1985), soaking (East *et al.*, 1972) and germination (Hsu *et al.*, 1980), have been used to increase the utilization of legumes.

Ekpenyong & Borchers (1980) investigated the effect of soaking and cooking methods on the chemical composition and digestibility of winged beans. They found that there was an increase in protein content, total carbohydrates and digestibility in the samples subjected to soaking and cooking.

*New address: Department of Applied Microbiology and Food Science, University of Saskatchewan, 51 Campus Drive, Saskatoon, SK, Canada S7N 5A8.

Akinyele & Akinlosotu (1991) studied the effects of soaking and dehulling on the oligosaccharides of cowpeas. It was found that 4 h soaking of cowpea seeds in water led to a 49% decrease in verbascose, 30% in stachyose and 1.0% in raffinose. Dehulling of the cowpeas resulted in a decrease of 76% in verbascose, 17% in stachyose and 56% in raffinose.

Ogun *et al.* (1989) studied the effects of dehulling, cold-soaking, hot-soaking and traditional cooking methods on certain anti-nutritional factors in cowpea. They observed that trypsin inhibitor was greatly reduced by the application of heat. It was found that dehulling had no effect on the trypsin inhibitory capacity of cowpeas.

Ayyagari *et al.* (1989) studied the effects of processing on lectins, trypsin inhibitors and tannins in legumes and cereals. Trypsin inhibitors and lectins were found to be inactivated to a considerable extent during cooking, but dry heating did not reduce the lectins activity. Dry heating or deep frying for less than 10 min was found to inactivate only 40–50% trypsin inhibitors. Samples subjected to heat treatment at temperatures above 100°C for long periods in the presence of water (steaming, boiling) did not contain any residual trypsin inhibitor activity.

Little information could be found on the interactive effect of soaking, water-blanching and soaking steam-blanching on the nutrients and anti-nutritional factors in cowpea. Therefore, the objectives in this study were to investigate the combined effects of soaking, water-blanching and steam-blanching on nutrients and anti-nutritional factors and to develop predictive models for these low cost processing options using response surface methodology (RSM). Optimization of these low cost appropriate technology processing options for use in developing countries is important to maximize their nutritional value, but may have additional benefits such as reducing fuel (firewood) consumption.

MATERIALS AND METHODS

Materials

Cowpeas (California blackeyes) were obtained from a local health food store. The moisture content was 8·08% dry basis.

Experimental design

Response surface methodology (RSM) (Wang *et al.*, 1996) was used to investigate the combined effects of soaking, germination time and temperature on the germination process, to optimise it.

In this study, the processing (system) was affected by two independent variables (factors), Z_i, i.e. soaking time and water-blanching time/steam-blanching time. The dependent variables (responses), Y, were total solids loss, protein, fat and ash contents and anti-nutritional factors. A mathematical function, f, to describe the relationship between responses, Y, and factors, Z_i, is as follows:

$$Y = f(Z_1, Z_2). \quad (1)$$

A second degree polynomial equation was assumed to approximate the true relationship between Y and Z_i

$$Y = b_0 + \sum_{i=12} b_i X_i + \sum_{i=12} b_{ii} X_i^2 + b_{12} X_1 X_2 \quad (2)$$

where b_o, b_i, b_{ii}, and b_{12} are constant coefficients and X_{is} are the coded independent variables linearly related to Z_i. The coding of Z_i into X_i was given by Wang *et al.* (1996). The levels of the variables in coded (X_i) and uncoded (Z_i) form are given in Table 1. The experimental design, which consisted of three variables at five levels with 16 runs, is shown in Tables 2 and 3.

Processing of cowpeas

Cowpea seeds were washed with tap water and then soaked in tap water at room temperature for different times (Table 1). For water blanching, soaked seeds were boiled in a pan at 100°C for different periods (Table 1). The ratio for soaking and water-blanching was 1:5. For steam-blanching, soaked seeds were blanched with steam in a vertical retort at 100°C at atmospheric pressure for different times (Table 1). Both water- and steam-blanched seeds were frozen and then freeze-dried, as were the unprocessed seeds. The freeze-dried seeds

Table 1. Values of independent process conditions and their corresponding levels and times

Independent variables	Symbol		Levels				
	Coded	Uncoded	−1·414	−1	0	+1	+1·414
Soaking time (h)	X_1	t_1	0	2·33	8	13·67	16
Water-blanching time (min)	X_2	t_2	0	5·87	20	34·13	40
Steam-blanching time (min)	X_3	t_3	0	5·87	20	34·13	40

Table 2. Experimental data for the nine responses under different soaking and water-blanching times

Run	Factors		Responses								
	X_1	X_2	Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
1	+1	+1	9.75	22.8	1.53	2.31	77.5	0.54	0.74	2.79	1.13
2	+1	−1	3.66	24.2	1.58	2.82	28.5	3.74	0.95	4.11	1.72
3	−1	+1	6.87	23.4	1.53	2.58	75.9	0.57	0.80	3.69	1.53
4	−1	−1	1.08	24.7	1.58	3.31	25.3	5.07	0.99	5.08	2.42
5	1.414	0	5.62	24.0	1.55	2.47	64.5	1.04	0.87	3.51	1.31
6	−1.414	0	1.72	24.5	1.56	2.90	62.9	1.97	0.93	4.75	2.05
7	0	1.414	11.2	22.5	1.53	2.35	79.2	0.71	0.74	2.70	1.04
8	0	−1.414	2.37	24.4	1.60	3.21	0.00	6.15	0.99	4.83	2.31
9	0	0	2.97	24.3	1.56	2.68	65.1	1.02	0.90	3.58	1.61
10	0	0	2.86	24.3	1.55	2.73	65.1	1.02	0.90	3.65	1.50
11	0	0	3.01	24.2	1.56	2.66	62.3	1.02	0.89	3.56	1.59
12	0	0	2.94	24.4	1.56	2.68	65.1	1.03	0.90	3.68	1.53
13	0	0	2.74	24.2	1.57	2.67	63.3	1.01	0.90	3.57	1.56
14	0	0	2.89	24.2	1.56	2.72	64.2	1.00	0.88	3.62	1.58
15	0	0	3.08	24.3	1.56	2.70	65.1	1.03	0.89	3.70	1.59
16	0	0	2.85	24.2	1.56	2.66	64.2	1.01	0.91	3.66	1.61

Table 3. Experimental data for the nine responses under different soaking and steam blanching times

Run	Factors		Responses								
	X_1	X_3	Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
1	+1	+1	2.84	24.2	1.57	3.02	78.0	0.49	0.91	4.39	2.06
2	+1	−1	2.74	24.4	1.58	3.07	20.0	3.62	0.93	4.54	2.16
3	−1	+1	1.32	24.5	1.58	3.19	76.3	0.51	1.04	5.10	2.56
4	−1	−1	0.97	24.6	1.58	3.25	17.6	4.92	1.05	5.19	2.67
5	1.414	0	2.70	24.1	1.57	3.01	80.2	0.91	0.93	4.25	1.99
6	−1.414	0	0.66	24.6	1.58	3.24	8.7	1.83	1.11	5.30	2.59
7	0	1.414	2.54	24.4	1.60	3.11	82.9	0.70	0.98	4.87	2.17
8	0	−1.414	2.37	24.5	1.60	3.21	0.00	6.07	0.99	4.92	2.31
9	0	0	2.48	24.4	1.57	3.12	73.9	1.00	1.01	4.84	2.22
10	0	0	2.38	24.7	1.58	3.08	75.6	0.98	1.00	4.79	2.22
11	0	0	2.44	24.4	1.57	3.11	74.4	1.00	0.98	4.86	2.31
12	0	0	2.54	24.4	1.58	3.14	75.4	1.00	1.00	4.88	2.23
13	0	0	2.45	24.4	1.59	3.17	73.2	1.02	0.98	4.87	2.16
14	0	0	2.59	24.4	1.58	3.12	72.4	1.01	1.01	4.82	2.18
15	0	0	2.44	24.3	1.58	3.04	74.5	1.01	1.00	4.78	2.21
16	0	0	2.40	24.5	1.58	3.08	75.7	1.00	1.01	4.86	2.31

were ground into flour with a coffee grinder for further analysis.

Chemical analysis

Proximate composition
Moisture content, crude protein (N×6.25), fat (ether extraction) and ash content were estimated by standard methods (AOAC, 1984).

Trypsin inhibitor activity (TIA)
Trypsin inhibitor levels were determined by the method of Smith *et al.* (1980).

Determination of oligosaccharides by HPLC
Oligosaccharides in cowpea were determined by high performance liquid chromatography (HPLC) according to Wang *et al.* (1996).

Degree of starch gelatinization
Degree of starch gelatinization was determined by the method of Birch & Priestley (1973).

RESULTS AND DISCUSSION

The eqn (2) was fitted to the experimental data (Tables 2 and 3) using SAS (SAS, 1985). The regression coefficients of eqn (2) are given in Tables 4 and 5. The analysis of variance for the model for the nine response variables (Tables 6 and 7) indicated that the model for the eight response variables, except for starch gelatinization, was statistically acceptable at the 1% level, possessing no lack of fit. Therefore, the model could be used to predict the response variables during soaking and blanching processes.

Effect of soaking, water- and steam-blanching on the nutrient contents

Figure 1 shows the interactive effect of soaking time water- and steam-blanching time on total solids loss. Total solids loss increased steadily as soaking time increased (Fig. 1(a,b)). There was a sharp increase in total solids loss with the increase in water-blanching time while steam-blanching time had little effect on

Table 4. Values of the regression coefficients of the second order polynomials representing the relationship between the indicated nine response variables and the independent variables of soaking and water-blanching time

Coefficient	Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
b_0	2.917	24.3	1.560	2.7	64.3	1.02	0.896	3.50	1.57
b_1	1.372	−0.222	−0.002	−0.171	0.887	−0.335	−0.022	−0.452	−0.271
b_2	3.037	−0.671	−0.026	−0.306	26.444	−1.925	−0.095	−0.717	−0.408
b_{11}	0.407	−0.046	−0.002	0.003	−0.253	0.245	−0.003	0.307	0.060
b_{12}	0.075	−0.058	−0.003	0.055	−0.415	0.325	−0.006	0.018	0.077
b_{22}	1.953	−0.411	0.001	0.053	−12.310	1.209	−0.018	0.123	0.058

Table 5. Values of the regression coefficients of the second order polynomials representing the relationship between the indicated nine response variables and the independent variables of soaking and steam-blanching times

Coefficient	Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
b_0	2.465	24.4	1.58	3.1	74.4	1.00	0.997	4.84	2.23
b_1	0.772	−0.136	−0.0015	−0.083	13.147	−0.328	−0.063	−0.357	−0.233
b_2	0.086	−0.057	−0.0024	−0.032	29.224	−1.893	−0.006	−0.039	−0.050
b_{11}	−0.418	−0.021	−0.0039	0.004	−13.704	0.184	0.008	−0.040	0.053
b_{12}	−0.063	−0.010	−0.0008	0.003	−0.168	0.322	−0.003	−0.015	0.001
b_{22}	−0.030	0.036	0.0076	0.024	−15.217	1.194	−0.010	0.020	0.027

Table 6. Analysis of variance table showing the effect of soaking and water-blanching time as a linear term, quadratic term and interactions on the nine response variables

Source	df	Sum of squares for								
		Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
Model	5	120.698**	5.38**	0.0057**	1.019**	6813**	43.1**	0.0786**	6.63**	1.99**
Linear	2	88.849**	3.998**	0.0056**	0.984**	5599.881**	30.553**	0.0758**	5.752**	1.915**
Quadratic	2	31.827**	1.370**	0.0000	0.023**	1212.189**	12.165**	0.0027*	0.875*	0.055**
Cross Product	1	0.023	0.013	0.0000	0.012**	0.689	0.422**	0.0001	0.001	0.024**
Residual	10	0.146	0.054	0.0002	0.0086	28.241	0.0014	0.0013	1.019	0.024
Lack of fit	3	0.068	0.030	0.0000	0.0034	20.479*	0.0008	0.0008	0.015	0.014
Pure error	7	0.078	0.024	0.0002	0.0053	7.762	0.0005	0.0005	1.004	0.010

**Significant at 1% level.
*Significant at 5% level.

Table 7. Analysis of variance table showing the effect of soaking and steam-blanching times as a linear term, quadratic term and interactions on the nine response variables

Source	df	Sum of squares for								
		Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
Model	5	6.243**	0.187**	0.0007*	0.069**	11568**	41.6**	0.033**	1.05**	0.485**
Linear	2	4.826**	0.173**	0.0001	0.064**	8213.974**	29.508**	0.032**	1.030**	0.456**
Quadratic	2	1.402**	0.014	0.0006**	0.005	3353.862**	11.681**	0.001*	0.016*	0.029*
Cross Product	1	0.016	0.000	0.0000	0.000	0.112	0.415**	0.000	0.001*	0.000
Residual	10	0.080	0.036	0.0005	0.0128	1233.082	0.0016	0.002	0.018	0.042
Lack of fit	3	0.046	0.018	0.0002	0.0003	1223.194**	0.0009	0.001	0.008	0.022
Pure error	7	0.034	0.017	0.0003	0.0125	9.888	0.0007	0.001	0.010	0.020

**Significant at 1% level.
*Significant at 5% level.

total solids loss (Table 9). Soaking and water-blanching time had a significant effect on total solids loss. Total solids loss rose sharply when soaking and water-blanching time increased. Therefore, steam-blanching had less total solids loss than water-blanching.

The combined effect of soaking, water- and steam-blanching on protein content is presented in Fig. 2. Both soaking and water-blanching had an influence on protein content (Table 8). Protein content decreased steadily with an increase in soaking and water-blanching time (Fig. 2a). Steam-blanching had little effect on protein content (Table 9 and Fig. 2b). However, Edijala (1980) studied the effects of soaking, cooking, decortication and conversion to a paste product on protein content of six cowpea varieties. It was found that all the processing methods showed small increases in protein contents for six cowpea varieties, ranging from 1·2–4·0%.

Figure 3 shows the combined effect of soaking time, water-blanching and steam-blanching time on ash content. Ash content decreased with increasing soaking time. Water-blanching had a significant effect on ash content while steam-blanching had little effect on ash

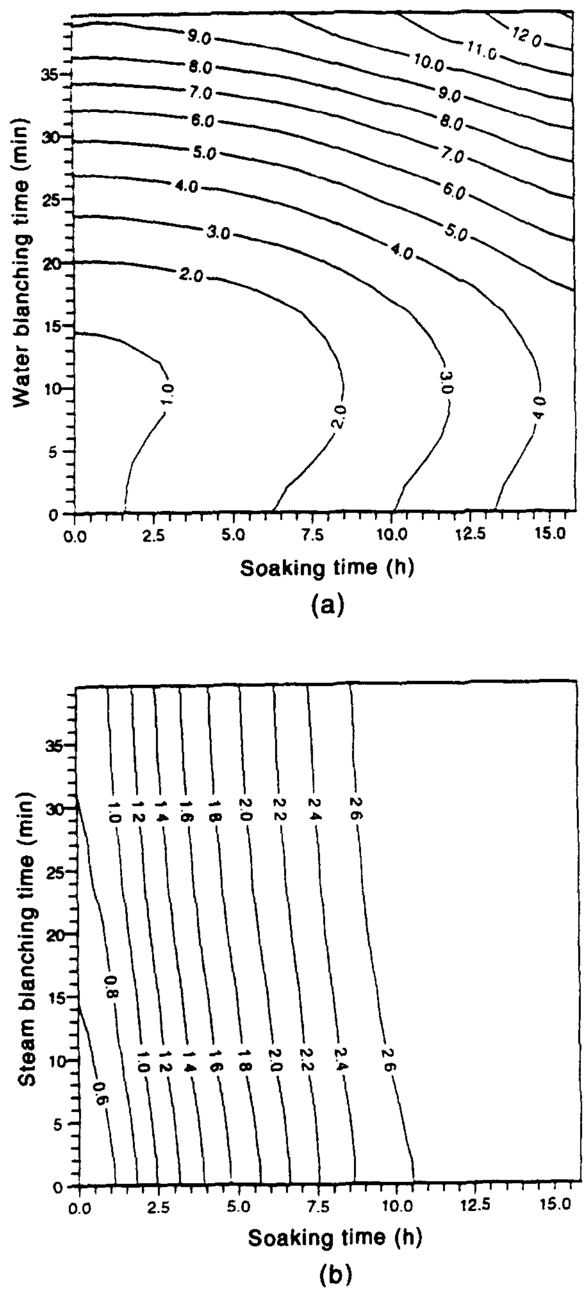

Fig. 1. Effect of soaking, water and steam blanching on total solids loss.

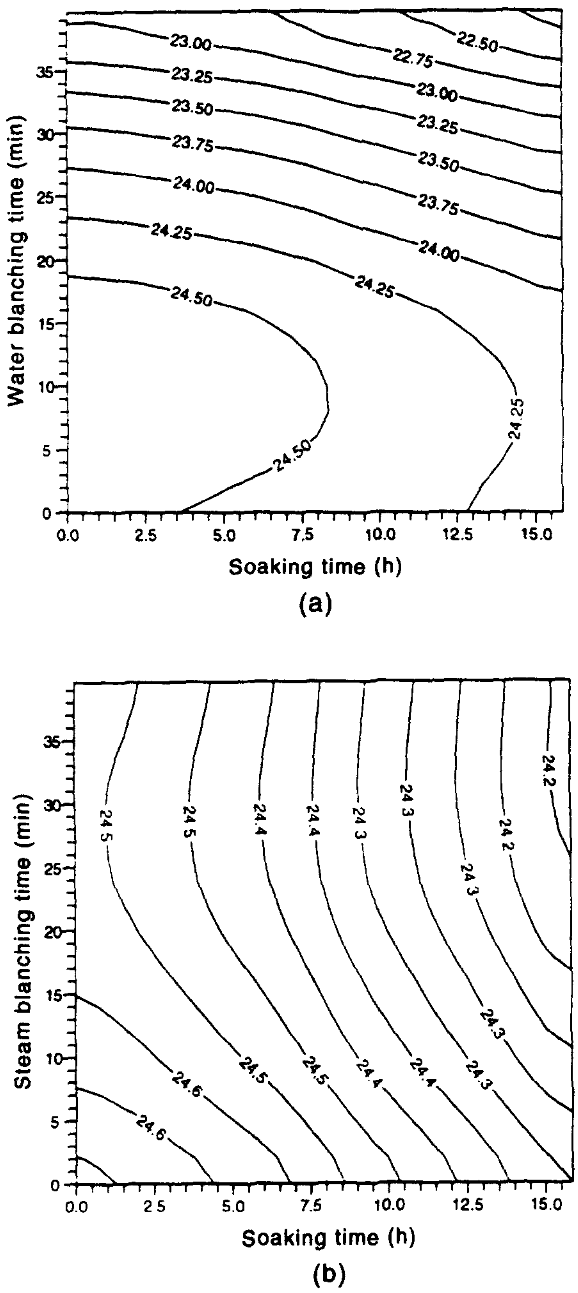

Fig. 2. Effect of soaking, water and steam blanching on protein content in cowpeas.

Table 8. Analysis of variance for the overall effect of the two process variables (soaking and water-blanching times) on the nine responses

Process variables	df	Sum of squares for								
		Solids loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
Soaking time (h)	3	16.408**	0.425*	0.0001	0.247**	7.50	1.80**	0.0043**	2.39**	0.638**
Water-blanching time (min)	3	104.311**	4.969**	0.0056*	0.261**	6805.945**	41.76**	0.0745**	4.238**	1.379**

**Significant at 1% level.
*Significant at 5% level.

Table 9. Analysis of variance for the overall effect of the two process variables (soaking and steam-blanching times) on the nine responses

Process variables	df	Sum of squares for								
		Solid loss (% dry wt)	Protein (% dry wt)	Fat (% dry wt)	Ash (% dry wt)	(%) Degree of starch gelatinization	TIA (mg/g)	Raffinose (% dry wt)	Stachyose (% dry wt)	Sucrose (% dry wt)
Soaking time (h)	3	6.176**	0.151*	0.0001	0.0560**	2683**	1.55**	0.0319**	1.03**	0.459**
Steam-blanching time (min)	3	0.082	0.037	0.0005	0.0131	8683.230**	40.47**	0.0011	0.017	0.026

**Significant at 1% level.
*Significant at 5% level.

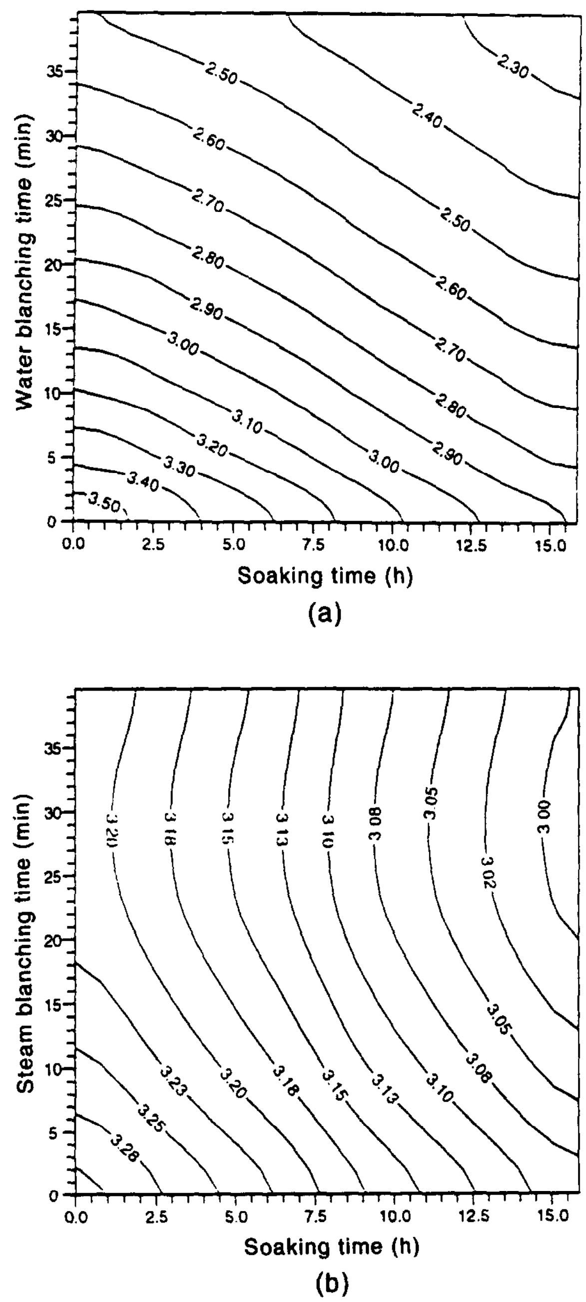

Fig. 3. Effect of soaking, water and steam blanching on ash content in cowpeas.

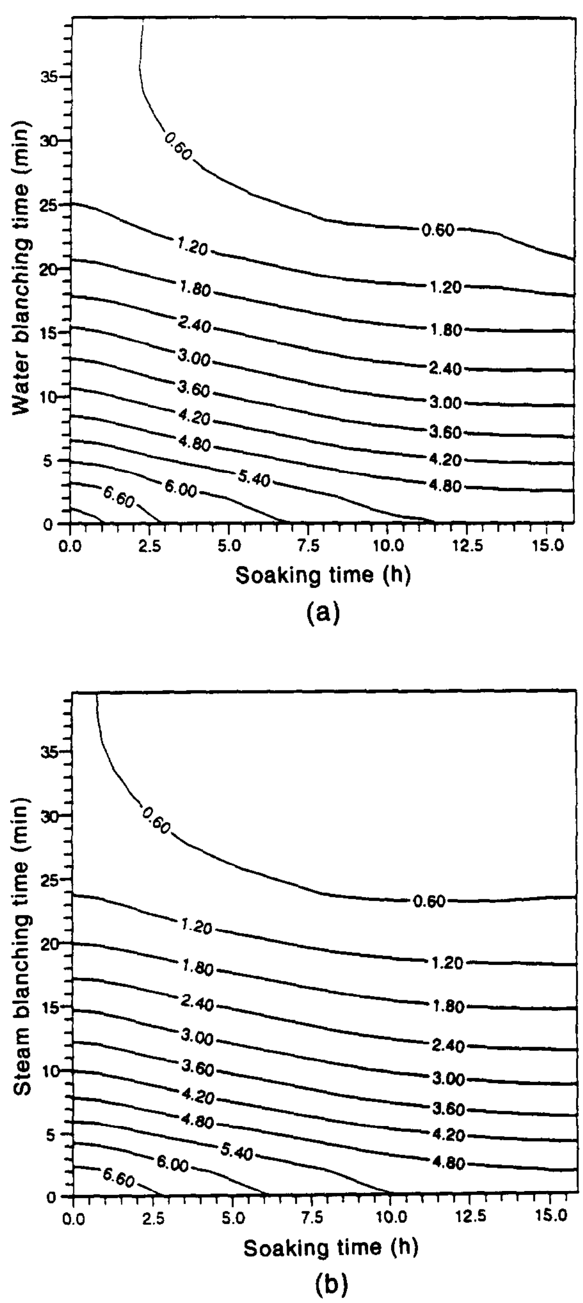

Fig. 4. Effect of water, soaking and steam blanching on trypsin inhibitor activity in cowpeas.

content (Tables 8 and 9). Ash content decreased as water-blanching time increased.

Akinyele (1989) studied the effect of household preparation methods of cowpea on the nutrient content of the various end products, ewa (boiled whole bean), akara (fried dehulled cowpea paste), moinmoin (steam-dehulled cowpea paste) and gbegiri (cowpea soup). It was found that the protein content was little affected by processing, but fat and ash contents were significantly affected by the methods of preparation.

Effect of soaking, water- and steam-blanching on the anti-nutritional factors

Effect on trypsin inhibitor activity (TIA)

The mean TIA value for the raw cowpea was found to be 6·99 mg/g. Kochhar *et al.* (1988) reported TIA values for different varieties of cowpea in a range of 4·6–13·9 mg/g. The TIA value in this study fell within the range of published results.

Figure 4 represents the combined effect of soaking, water- and steam-blanching on TIA. TIA decreased steadily with increasing soaking time. It can also be seen from Fig. 4 that TIA decreased sharply with an increase in water- and steam-blanching times. It was found that steam-blanching reduced TIA more effectively than water-blanching (at 5% level). Gatfield (1980) investigated the effect of soaking upon the trypsin inhibitor activity of legumes. It was found that legumes lost a certain amount of inhibitor activity as a result of leaching during soaking.

Rackis (1966) studied the effect of steam-blanching on anti-nutritional factors of soybean products. It was found that the trypsin inhibitor activity decreased by at least 95% from an average initial value of 35 mg to about 0·8–1·1 mg inhibitor per g of meal. For dehulled beans (cotyledons), 60–74% was destroyed after 20 min of steaming. Phillips & Adams (1983) found that steamed and decorticated cowpeas reduced in trypsin inhibitor activity by 60% from whole cowpeas.

Roman *et al.* (1987) reported that 28% of trypsin inhibitor was removed during soaking. Cooking eliminated 77% of the trypsin inhibitor initially present. Cooking (boiling 15 min) followed by roller drying destroyed 91% of trypsin inhibitor activity and autoclaving (15 min at 15 psi, 121°C) reduced 91%. Gatta *et al.* (1989) investigated trypsin inhibitor levels in some raw and cooked seeds of some cowpea varieties. The values of trypsin inhibitor found in raw seeds ranged from 27 to 66 TIU/mg protein, showing a broad variability among the varieties. A considerable reduction (80–90%) of trypsin inhibitor activity was found in all samples after cooking (autoclaving at 120°C for 30 min). Phillips & Adams (1983) found that steaming and decortication reduced TIA by 60% in whole cowpea. In this study, the combination of soaking and blanching reduced TIA more than 90% in cowpea. Heat treatments are more effective in removing TIA in cowpea than germination (Wang *et al.*, 1996).

Effect on oligosaccharides

The mean raffinose, stachyose and sucrose contents of the raw cowpea were 1·24, 5·53 and 2·74 (g/100 g dry basis), respectively. Akpapunam & Markakis (1979) and Onigbinde & Akinyele (1983) investigated the oligosaccharide contents of different varieties of cowpeas. They reported raffinose in the range of 1·1–4·12 (g/100 dry basis), of stachyose in the range of 1·21–4·84 g/100 dry basis, respectively. The values determined in the present study, except that for stachyose which was slightly higher than reported values, were within the range of published work.

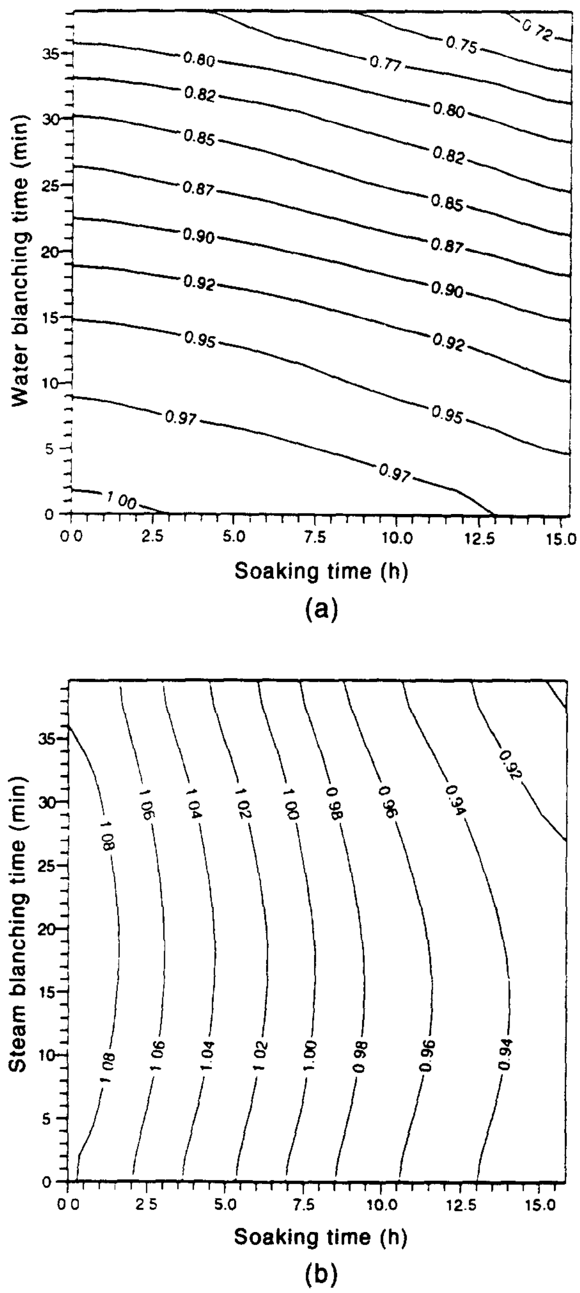

Fig. 5. Effect of soaking, water and steam blanching on raffinose content in cowpeas.

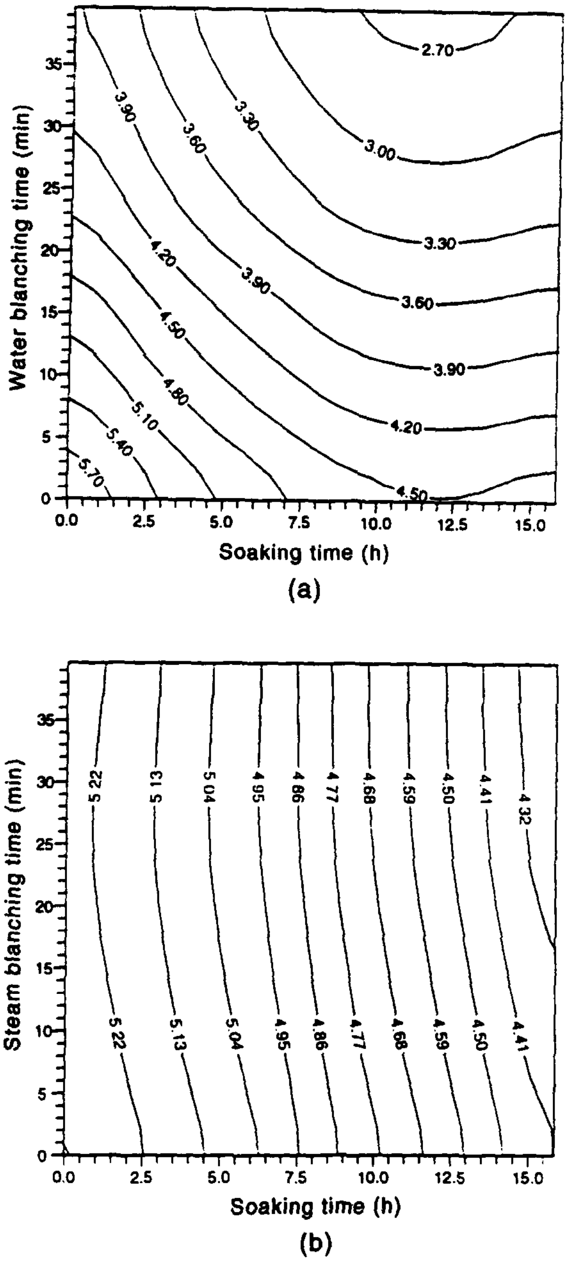

Fig. 6. Effect of soaking, water and steam blanching on stachyose content in cowpeas.

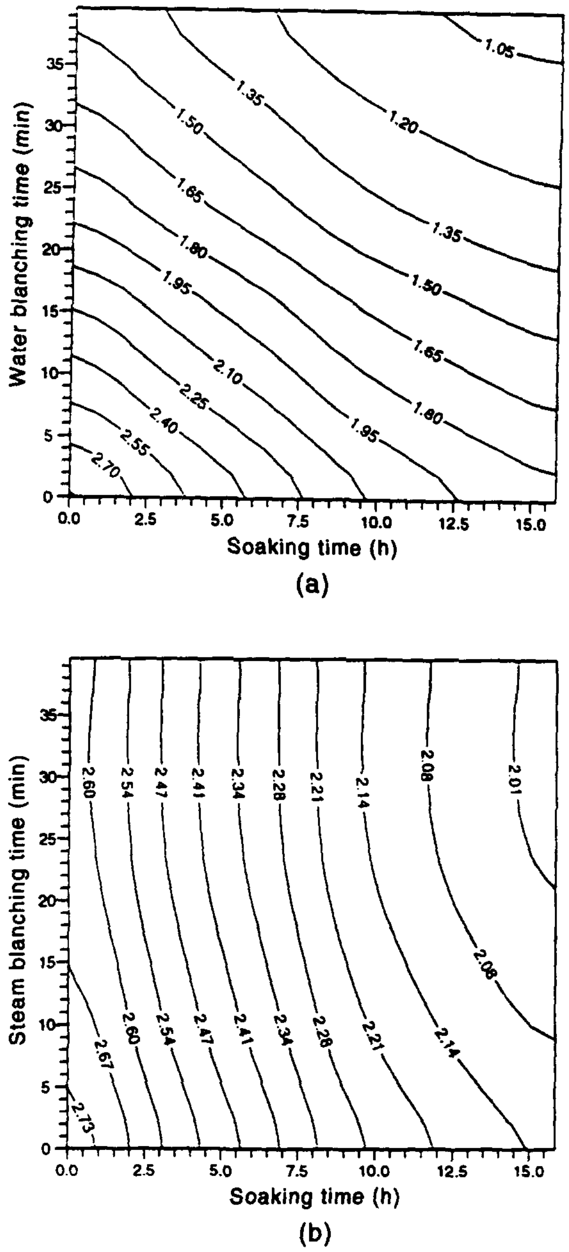

Fig. 7. Effect of soaking, water and steam blanching on sucrose content in cowpeas.

Figure 5 shows the effects of soaking, water- and steam-blanching on the raffinose content in cowpea. The raffinose content decreased steadily with an increase in soaking time (Fig. 5(a,b)). It was found that water-blanching had a significant effect on raffinose content while steam-blanching had little influence on raffinose content. The reduction in raffinose content during soaking and water-blanching is probably due to leaching of raffinose into water.

The same pattern as that for raffinose was found for stachyose and sucrose contents, as shown in Fig. 6 and Fig. 7. The combination of soaking and water-blanching was more effective in reduction of oligosaccharides than that of soaking and steam-blanching. The reductions for example, in raffinose and stachyose for soaking 8 h and water-blanching 20 min were 29 and 34%, respectively while for soaking 8 h and steam-blanching 20 min, they were 19 and 13%, respectively.

Jood *et al.* (1985) studied the effects of various treatments such as soaking, cooking and autoclaving on the oligosaccharide contents of five different legumes. They concluded that soaking for 12 h in water or sodium bicarbonate solution, followed by autoclaving, caused reductions of raffinose, stachyose and verbascose contents of the order of 60–90, 75–90 and 80–90%, respectively. Soaking in water followed by cooking resulted in a reduction in raffinose, stachyose and verbascose of 40–72, 49–77 and 40–80%, respectively. In this study the results fall within the range of reported work.

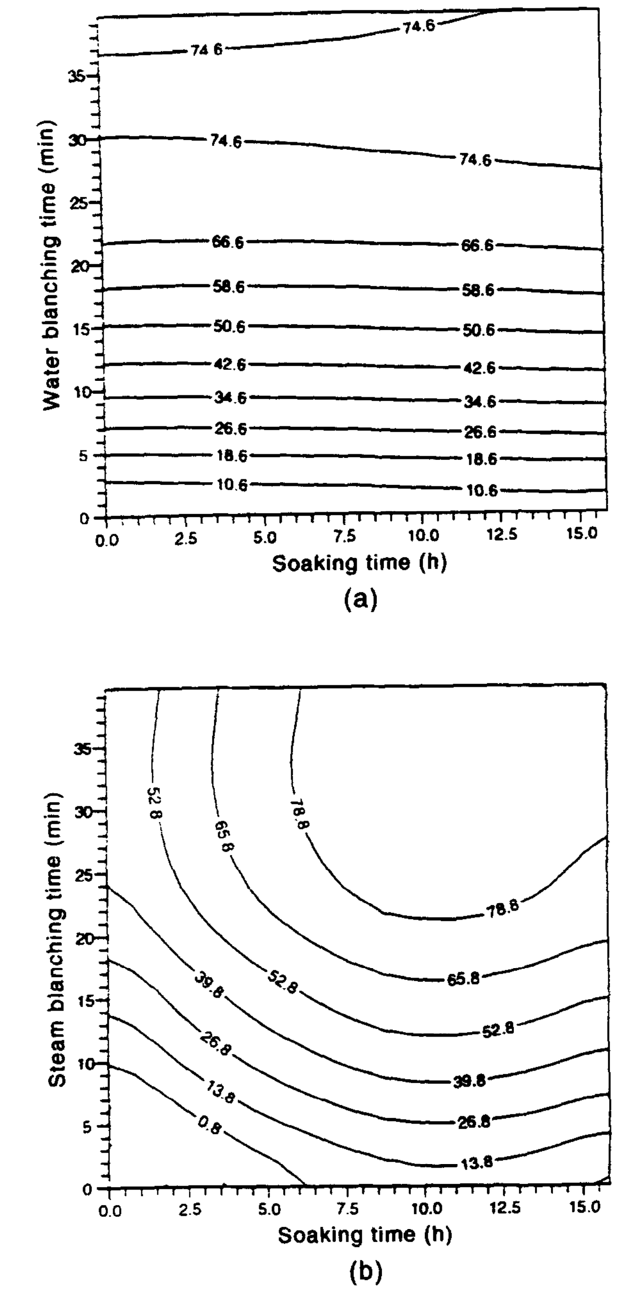

Fig. 8. Effect of soaking, water and steam blanching on starch gelatinisation in cowpeas.

Effect on the degree of starch gelatinization

Figure 8 shows the combined effect of soaking, water- and steam-blanching on degree of starch gelatinization. It can be seen from Fig. 8a that soaking had little effect on starch gelatinization, while water-blanching had a significant effect on starch gelatinization (Table 8). The degree of starch gelatinization increased sharply with an increase in water-blanching time.

Figure 8(b) represents the combined effect of soaking and steam-blanching on starch gelatinization. The pattern was different from that of soaking and water-blanching. It was found that soaking had an effect on the degree of starch gelatinization during steam-blanching. The effect of steam-blanching on the degree of starch gelatinization was greater than that of soaking and water-blanching (at 5% level).

These experimental results could be used to select the operating conditions to achieve any specified finished product compositional requirements, within the experimental range.

CONCLUSIONS

From this study it may be concluded that the combination of soaking and water-blanching and soaking and steam-blanching had significant effects on the reduction of TIA and oligosaccharides when compared with single processes. The combined effect of soaking and water-blanching on nutrient losses were greater than that of soaking and steam-blanching. The *in-vitro* protein digestibility of cowpea could be improved after such heat processing. Models for the prediction of total solids loss, protein, and ash contents, TIA, oligosaccharides and starch gelatinization were developed as functions of soaking time and water- steam-blanching time.

REFERENCES

Akinyele, I. O. (1989). Effects of traditional methods of processing on the nutrient content and some antinutritional factors in cowpeas (*Vigna unguiculata*). *Food Chem.*, **33**, 291–299.

Akinyele, I. O. & Akinlosotu, A. (1991). Effect of soaking, dehulling and fermentation on the oligosaccharides and nutrient content of cowpeas (*Vigna unguiculata*). *Food Chem.*, **41**, 43–53.

Akpapunam, M. A. & Markakis, P. (1979). Oligosaccharides of 13 American cultivars of cowpeas. *J. Food Sci.*, **44**, 1317–1321.

AOAC (1984). *Official Methods of Analysis*, Association of Official Analytical Chemists, Washington, D.C.

Ayyagari, R., Rao, B. S. N. & Roy, D. N. (1989). Lectins, trypsin inhibitors, BOAA and tannins in legumes and cereals and the effects of processing. *Food Chem.*, **34**, 229–238.

Birch, G. G. & Priestley, R. J. (1973). Degree of gelatinization of cooked rice. *Starch*, **3**, 98–100.

East, J. W., Nakayama, T. O. M. & Parkman, S. B. (1972). Changes in stachyose, raffinose, sucrose and monosaccharides during germination of soybeans. *Crop Sci.*, **12**, 7.

Edijala, J. K. (1980). Effect of processing on the thiamin, riboflavin and protein contents of cowpea (*V. unguiculata*) 1. soaking, cooking and wet milling processes. *J. Food Technol.*, **15**, 435–443.

Ekpenyong, T. E. & Borchers, R. L. (1980). Effect of cooking on the chemical composition of winged bean (*Psophocarpus tetragonobolus*). *J. Fd Sci.*, **45**, 1559.

Gatfield, I. L. (1980). Loss of dry matter during the industrial preparation of legumes: leaching of trypsin inhibitors from beans during the soaking step. *Lebensmitt.-Wiss. U.-Technol.*, **13**(1), 46–48.

Gatta, C. D., Piergiovanni, A. R., Ng, N. Q., Carnovale, E. & Perrino, P. (1989). Trypsin inhibitor levels in raw and cooked cowpea (*Vigna unguiculata*) seeds. *Lebensm.-Wiss.U.-Technol.*, **22**, 78–80.

Giovanni, M. (1983). Response surface methodology and product optimization. *Food Technol.*, **11**, 41–83.
Hsu, D., Leung, H. K., Finney, P. L. & Moran, M. M. (1980). Effect of germination on nutritive value and baking properties of dry peas, lentils and faba beans. *J. Food Sci.*, **45**, 87.
Jood, S., Mehta, U., Singh, R. & Bhat, C. M. (1985). Effect of processing on flatus producing factors in legumes. *J. Agric. Food Chem.*, **33**, 268.
Kennedy, I. R., Mwandemele, O. D. & McWhirter, K. S. (1985). Estimation of sucrose, raffinose and stachyose in soybean seeds. *Food Chem.*, **17**, 85–93.
Kochhar, N., Walker, A. F. & Pike, D. J. (1988). Effect of variety on protein content, amino acid composition and trypsin inhibitor activity of cowpeas. *Food Chem.*, **29**, 65–78.
Myers, R. H. (1971). *Response Surface Methodology*, Allyan and Bacon, Boston.
Ogun, P. O., Markakis, P. & Chenoweth, W. (1989). Effect of processing on certain antinutrients in cowpeas (*Vigna unguiculata*). *J. Food Sci.*, **54**(4), 1084–1085.
Onigbinde, A. O. & Akinyele, I. O. (1983). Oligosaccharide content of 20 varieties of cowpeas in Nigeria. *J. Food Sci.*, **48**, 1250–1254.
Phillips, R. D. & Adams, J. G. (1983). Nutritional and physiological response of rats to diets containing whole, decorticated and steamed cowpeas. *Nutr. Rep. Int.*, **27**, 949.
Rackis, J. J. (1966). Soybean trypsin inhibitors: their inactivation during meal processing. *Food Technol.*, **20**, 1482–1484.
Roman, A. V., Bender, A. E. & Morton, I. D. (1987). Formulation and processing of a weaning food based on rice cowpeas and skim milk powder human nutrition. *Food Sci. Nutr.*, **41F**, 15–22.
SAS (1985). *SAS User's guide: Statistics*, Version 5 edition, SAS Institute Inc., Cary, NC.
Sathe, S. K. & Salunkhe, D. K. (1981). Preparation and utilization of protein concentrates and isolates for nutritional and functional improvement of foods. *J. Food Qual.*, **4**, 145–233.
Smith, C., Megen, W. V., Twaalfhoven, L. & Hitchcock, C. (1980). The determination of trypsin inhibitor levels in foodstuffs. *J. Sci. Food Agric.*, **31**, 321–350.
Wang, N., Lewis, M. J., Brennan, J. G. & Westby, A. (1996). Optimization of germination process of cowpea by response surface methodology. *Food Chem.* (submitted).