Food Chemistry **22** (1986) 165–175

Evaluation of Soymilk and Other Soy Products Derived from Defatted Soymeal

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(Received: 4 April, 1986)

ABSTRACT

An evaluation study was carried out on soymilk reconstituted from soymilk powder which in turn was obtained through spray-drying of soymilk formulated from defatted soymeal. The colour and stability of the reconstituted soymilk were found to be dependent on the relative levels of oil and emulsifier added to the formulation. A 2^3 factorial experiment was designed to determine the effect of protein, oil and emulsifier levels on the colour and stability of the soymilk. Using a Hedonic preference test, the acceptability of the reconstituted soymilk formulated on the basis of results from the 2^3 factorial experiment was assessed and compared with commercial samples of soymilk.

INTRODUCTION

Soymilk is widely accepted as a nutritious drink in the East as its beany flavour, in contrast to the West, is well accepted by Eastern palates. As part of our study on the development of low cost protein-rich foods, a method has been established (Ang *et al.*, 1985) for the preparation of soymilk powder from defatted soymeal through spray-drying (Hall & Hedrick, 1972; Master, 1972; Aminlari *et al.*, 1977). It was found that soymilk can be readily reconstituted from the spray-dried soymilk powder (Ang *et al.*, 1985). The nutritional values of the soymilk thus

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obtained have been ascertained by a series of analyses (Van Buren *et al.*, 1964; Aminlari *et al.*, 1977; Ang *et al.*, 1985). However, it was found that the colour and stability of the soymilk, formulated from defatted soymeal, are dependent on the relative levels of oil and emulsifier added to the defatted soymeal. As the colour and stability of the reconstituted soymilk would determine its acceptability, a 2^3 factorial experiment was designed to determine the effect of protein, oil and emulsifier levels on the colour and stability of the soymilk formulated from defatted soymeal. The results of a Hedonic preference test for assessment of the acceptability of the soymilk, reconstituted on the basis of the findings from the 2^3 experiment, are now presented.

EXPERIMENTAL

Preparation of milk

The required addition of defatted soyflour to water was blended in a National blender for 10 min. The slurry was allowed to stand to permit the foam to settle, after which it was filtered through one layer of cheese cloth. The filtrate was preheated to boiling and the required amount of sugar was added, followed by oil and emulsifier. This was homogenised in a blender, after the froth had settled. The product was filled into soft drink bottles (*ca.* 287 ml) crowned with bottle caps and sterilised in an autoclave at 120°C for 15 min.

The samples produced at various protein levels were set aside at ambient temperature and examined daily for precipitation. Colour was measured using a Lovibond Tintometer and comparison with a commercial product. On the use of different emulsifiers, which tend to impart a flavour to the product, an organoleptic test was carried out to ascertain the least objectionable emulsifier amongst sodium carboxymethyl cellulose, sorbitan monolaurate and gum acacia. This was done using a small taste panel drawn from the staff of the Department. Two commercial products were included in the test for assessment. Oil level was varied from 0·2% to 1·0% w/v. The milk products obtained were judged visually for degree of whiteness on a 5-point scale, where 1 represents light brownish and 5, milky white. From the data obtained from these preliminary trials, the 2-level, 3-factors factorial experiment was designed. Details of the Design Matrix are explained below. The factors under study were protein, oil and emulsifier contents and the response variables were colour, as measured by taste panel procedure, and stability in the form of number of precipitation-free days.

Formulation of soymilk from defatted soymeal

Defatted soymeal is obtained in large quantities as the by-product from a local soybean oil production plant. It has, however, been found that the intensive heat treatment of the defatted meal during the removal of residual solvent (hexane) leads to severe denaturation of the protein (Kellor, 1974). Thus, for the formulation of soymilk from the meal, samples of the defatted meal were laboratory dried by means of a fluidised bed drier in place of the desolventiser–toaster used in the plant. As the use of the fluidised bed drier involved only mild heat treatment, the extent of protein denaturation was much reduced, as was supported by the relatively higher nitrogen solubility index (Van Buren *et al.*, 1964) of the defatted meal thus obtained (Table 1).

Samples of soymilk were then formulated using varying percentages of protein (defatted soymeal), emulsifier and oil. It was found that the stability (Table 2) and the degree of whiteness (Table 3) of the soymilk generally decreased with increasing protein content but the latter also

TABLE 1
Composition of Defatted Meal (%)

	A	*B*
Total protein[a]	49·3	50·3
Nitrogen solubility index[b]	4	73
Oil[a]	0·3	0·6
Crude fibre[a]	3·3	3·2
Carbohydrates	27·3	27·6
Total ash[c]	5·9	5·9
Moisture[c]	12·9	12·4
Urease activity[d]	0·0	2·1

A: Defatted soymeal from the desolventising chamber.
B: Defatted soymeal from the conveyor belt before entering the desolventising chamber.
[a] Pearson (1976); Egan *et al.* (1981).
[b] Aminlari *et al.* (1977).
[c] AOAC (1975).
[d] Anon (1970).

TABLE 2
Stability versus Protein Level

Protein content (%)	*Colour*	*Number of days storage without precipitation*
2·0	Greyish	19
1·5	Greyish	15
1·0	White	40
0·5	White	40

TABLE 3
Colour versus Protein Level

Protein content (%)	*Lovibond readings*		
	Red	*Yellow*	*Blue*
3·0	4·3	10·0	3·5
2·5	4·0	9·5	3·3
2·0	4·0	9·1	3·1
1·5	3·0	8·2	2·4
1·0	2·8	7·0	2·9
0·5	2·0	4·4	2·2

TABLE 4
Study of Colour versus Oil Level

Palm oil (%)	*Colour score*
0·2	2
0·3	3
0·4	4
0·6	5
0·8	5
1·0	5

Colour score 1 (light brown) to 5 (milk white).

Formulation
0·05% emulsifier
0·3% palm oil
10% sugar
One drop diluted banana flavour
} Fixed composition

TABLE 5
Effect of Emulsifier Type and Flavour Acceptability.
Formulation: 2% Protein; 10% Sugar, 0·3% Oil

Sample flavour score panelist	*Commercial A*	*Commercial B*	*0·05% sorbitan monolaurate*	*0·05% sodium CMC*	*0·05% gum acacia*
1	5	2	4	3	6
2	5	4	3	2	5
3	6	5	3	6	5
4	5	7	6	4	5
5	5	5	3	6	5
6	4	4	1	4	2
7	6	5	4	4	6
Total	36	32	24	29	34

Flavour score 1 (undesirable) to 7 (very desirable).

increased with the oil content (Table 4). Of the different emulsifiers employed in the formulation study, gum acacia was found to be most acceptable (Table 5).

Based on the above findings, a 2^3 factorial design experiment (Perry, 1963) was carried out to study, systematically, the effect of protein, oil and emulsifier levels on the colour and stability of soymilk formulated from defatted soymeal.

The design matrix is as shown in Table 6. Colour (degree of whiteness) and stability are the response variables under monitor; the former were assessed by subjective colour panel procedure, while the latter was determined by the number of precipitation-free days under storage at ambient temperatures.

The linear first-order model proposed to fit the data from the above experiment is then given by the following equations:

$$W = \alpha + \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_{12} X_1 X_2 + \alpha_{13} X_1 X_3 + \alpha_{23} X_2 X_3 + \alpha_{123} X_1 X_2 X_3 \quad (1)$$

$$S = \beta + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3 \quad (2)$$

where W and S, as well as X_1, X_2 and X_3, are defined in Table 6 and the parameters α_1, $\beta_1, \ldots, \beta_{123}$ are to be determined.

TABLE 6
Design Matrix of 2^3 Factorial Experiment on Emulsifier, Oil and Protein Level

Factors	*Symbol*	*Low (%)*	*High (%)*
Emulsifier	E	0·03	0·1
Oil	ϕ	0·3	1·0
Protein	P	1·0	2·0
Fine Ingredient			
Sugar	10%		
Flavour	To taste		
Response Variables			
Colour (whiteness)	W	Evaluated subjective by panel	
Stability	S	Number of precipitation-free days	
Transformation		*Low*	*High*
Emulsifier	$X_1 = \frac{E - 0{\cdot}065}{0{\cdot}035}$	-1	$+1$
Oil	$X_2 = \frac{\phi - 0{\cdot}65}{0{\cdot}35}$	-1	$+1$
Protein	$X_3 = \frac{P - 1{\cdot}5}{0{\cdot}5}$	-1	$+1$

Run	*Code*	X_1	X_2	X_3
1	T_8	−	−	−
2	P_5	+	−	−
3	L_3	−	+	−
4	S_9	+	+	−
5	F_7	−	−	+
6	V_4	+	−	+
7	C_2	−	+	+
8	M_6	+	+	+

Eight samples prepared as described in Table 6 were submitted for evaluation to an untrained panel of twenty-two members. These samples were placed randomly over a black sheet of paper in an enclosed room lighted by fluorescent lamps. Each panelist was asked:

(1) to rate the colour on a ten-point scale where the uppermost end of the scale, '10', represents 'very white' and the lowest end, '0' represents 'pale greyish'

TABLE 7
Panel Evaluation of the Degree of Whiteness and Stability Tests of the Soymilk Prepared from Different Formulations as Laid Down in 2^3 Factorial Design Experiments

Code	*Emulsifier* X_1	*Oil* X_2	*Protein* X_3	*Mean panel score of whiteness* W	*Std. dev.*	*References colour in Lovibond units* R	Y	B	*Stability (days)* S
T_8	−	−	−	5·6	1·3	4·0	9·0	3·9	23
P_5	+	−	−	5·0	1·3	3·2	7·0	3·0	16
L_3	−	+	−	8·2	0·8	4·9	10·0	5·0	6
S_9	+	+	−	8·0	1·2	3·0	6·0	3·0	5
F_7	−	−	+	2·7	1·5	4·0	8·0	3·1	16
V_4	+	−	+	2·8	1·4	3·5	7·0	3·5	13
C_2	−	+	+	4·5	1·3	4·3	8·0	4·0	3
N_6	+	+	+	6·1	1·2	3·1	6·2	2·2	3
Acceptable level of whiteness				7·2	1·5				
Preferred products									
1st Choice:				S_9 (11)	L_3 (7)	N_6 (3)	P_5 (1)		
2nd Choice:				L_3 (7)	S_9 (6)	N_6 (4)	T_8 (3)		C_2 (2)

(2) to indicate the degree of whiteness acceptable to them
(3) to indicate two samples of their choice in terms of colour. These questions aim at:

(a) evaluating the degree of whiteness subjectively
(b) determining an acceptable level of whiteness
(c) confirming consumer choice of products in terms of colour

The responses to the factorial experiment, as well as stability as measured by the number of precipitation-free days, are given in Table 7. The coefficients in eqns (1) and (2) were then evaluated as shown in Table 8. The two equations that relate whiteness (W) and stability (S) to emulsifier (E), oil (ϕ) and protein (P) contents are then given by:

$$W = 7{\cdot}1 - 10{\cdot}3E + 5{\cdot}9\phi - 2{\cdot}4P - 20{\cdot}4E\phi + 0{\cdot}6EP + 2{\cdot}2\phi P + 265E\phi P \quad (1')$$

$$S = 45{\cdot}5 - 212{\cdot}2E - 35{\cdot}5\phi - 11{\cdot}0\phi P + 183{\cdot}7E\phi + 75{\cdot}5EP + 7{\cdot}6\phi P - 61{\cdot}2E\phi P \quad (2')$$

TABLE 8
Derivation of the Coefficients of Linear First Order Equations for Degree of Whiteness and Stability

Coefficients	*Formulae*	*Numerical values*
α, β	$\frac{W}{n}$	5·3625, 10·625
α_1, β_1	$\frac{1}{2}\left(\frac{W_2+W_4+W_6+W_8}{4}-\frac{W_1+W_3+W_5+W_7}{4}\right)$	0·1125, −1·375
α_2, β_2	$\frac{1}{2}\left(\frac{W_3+W_4+W_7+W_8}{4}-\frac{W_1+W_2+W_5+W_6}{4}\right)$	1·3375, −6·375
α_3, β_3	$\frac{1}{2}\left(\frac{W_5+W_6+W_7+W_8}{4}-\frac{W_1+W_2+W_3+W_4}{4}\right)$	−1·3375, −1·875
α_{12}, β_{12}	$\frac{1}{2}\left(\frac{W_1+W_4+W_5+W_8}{4}-\frac{W_2+W_3+W_6+W_7}{4}\right)$	0·2375, −1·125
α_{13}, β_{13}	$\frac{1}{2}\left(\frac{W_1+W_3+W_6+W_8}{4}-\frac{W_2+W_4+W_5+W_7}{4}\right)$	0·3125, 0·625
α_{23}, β_{23}	$\frac{1}{2}\left(\frac{W_1+W_2+W_7+W_8}{4}-\frac{W_3+W_4+W_5+W_6}{4}\right)$	−0·0875, −0·625
$\alpha_{123}, \beta_{123}$	$\frac{1}{2}\left(\frac{W_2+W_3+W_5+W_8}{4}-\frac{W_1+W_4+W_6+W_7}{4}\right)$	−0·1625, −0·375

To test the validity of these equations, samples of soymilk were formulated using varying percentages of emulsifier, oil and protein. The degrees of whiteness and stability of these samples were then examined. For samples with protein contents up to 2%, it was found that the degrees of whiteness and stability were close to those predicted by the above equations. For samples with protein contents greater than 2%, however, the degree of whiteness appeared to fall below the expected values.

An interesting finding from the response of the panel was that the acceptable level of whiteness on the ten-point scale was rated as 7·2 rather than the highest possible score of 10. This arose because the panelists expected the soymilk that was 'concentrated' and 'rich' to be 'creamy' in colour. Thus, a very white product was thought to give an appearance of artificiality.

It is significant to note that (1′) and (2′) are useful in determining the formulation for soymilk, not only of high protein content, but also of general acceptance.

As part of the study, a triangle test (Dotty, 1976; IFT Sensory Evaluation Division, 1981) was next carried out to ascertain whether consumers could detect any difference between the reconstituted spray-dried soymilk and the bottled, sterilised soymilk of the same formulation. A batch of soymilk was prepared and divided into two portions, one of which was bottled and sterilised and the other spray-dried into a powder. The powder was reconstituted into the original formulation by adding the appropriate quantity of water. The objective of this test (Powers & Moskowitz, 1968, 1976; Teranishi *et al.*, 1971) was to evaluate whether spray-drying and subsequent reconstitution would affect the flavour of the product and, if so, to what extent and, finally, whether there was a preference for one product over the other. Results of the test are shown in Table 9.

From the results, it appears that the difference between bottled milk and reconstituted milk could be detected by most tasters; however, in terms of acceptability, half of the panel preferred the bottled product

TABLE 9
Result of Triangle Test on Bottled and Reconstituted Soymilk

Identification	
Odd sample* identified correctly:	17
Odd sample* not identified correctly:	6
	23*
Degree of difference	*Actual score*
Slight	8
Moderate	3
Much	10
Extreme	2
Acceptability	
Odd sample	12
Duplicate sample* more acceptable	11

Odd sample—bottled soymilk.
Duplicate sample—reconstituted from spray-dried soymilk powder.

TABLE 10
Results of Hedonic Preference Test

Brand	*Total score*
Commercial soymilk A	170
Commercial soymilk B	150
Commercial soymilk C	141
Reconstituted soymilk	145

while the other half preferred the reconstituted product. The bottled product was slightly thicker in consistency and that was the main reason given by panelists who preferred this product. The reconstituted product, of about the same total solids as the bottled milk, appeared thinner and, ironically, that was the reason given by panelists for their preference.

To assess the acceptability of the product, a Hedonic preference test (Moncrieff, 1966; Moskowitz *et al.*, 1977) was carried out between the reconstituted soymilk from spray-drying and three other commercial products. A nine-point Hedonic scale was used (Peryam & Pilgrim, 1957) and thirty panelists participated in the test. Scores were converted into an integer scale for simplicity and results are shown in Table 10.

As the chemical score of the reconstituted product lies within the range 141–170 for the commercial samples of established acceptability, it is fairly certain that the soymilk from the spray-dried defatted meal is of high acceptability.

REFERENCES

Aminlari, M., Ferrier, L. K. & Nelson, A. I. (1977). Protein dispersibility of spray dried whole soybean milk base: Effect of processing variables. *J. Food Science*, **42**(4), 985–8.

Ang, H. G., Kwik, W. L. & Theng, C. Y. (1985). Development of Soymilk—A review. *Food Chemistry*, **17**, 235–50.

Anon (1970). *Official and tentative methods of the American Oil Chemists' Society* (3rd edn), American Oil Chemists' Society, Chicago.

AOAC (1975). *Official methods of analysis* (12th edn), Association of Official Analytical Chemists, Washington, DC.

Dotty, D. M. (1976). *Objective methods for food evaluations*. National Academy of Science, Washington, USA.

Egan, Harold, Kirk, Ronald, S. & Sawyer, Ronald (1981). *Pearson's Chemical Analysis of Foods*. Churchill Livingston, Edinburgh.

Hall, C. W. & Hedrick, T. I. (1972). *Drying of milk and milk products*, AVI Publishing Co., Westport, Conn.
IFT Sensory Evaluation Division (1981). Sensory evaluation guide for testing food and beverage products. *Food Technol.*, November, 50–9.
Kellor, R. L. (1974). Defatted soyflour and soygrits. *JAOCS*, **51**, 774–804.
Master, K. (1972). *Spray drying*, Leonard Hill, London.
Moncrieff, R. W. (1966). *Odour preference*, Leonard Hill, London.
Moskowitz, H. R., Dubose, C. N. & Reuber, M. J. (1977). Flavour chemical mixtures—A psychophysical analysis. In: *Flavour quality: Objective measurements* (Richard A. Scanlan (Ed.)). ACS Symposium Series 51, Washington, DC, 29–44.
Pearson, D. (1976). *The Chemical Analysis of Foods*, 7th edn. Churchill Livingston, Edinburgh.
Peryam, D. R. & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technol*, **11**(9).
Perry, John H. (1963). *Chemical engineering handbook*. (Perry, John H. (Ed.)), McGraw-Hill, New York.
Powers, J. J. & Moskowitz, H. R. (1968). *Correlation of subjective–objective methods in the study of odors and taste*. ASTM STP 440, American Society for Testing and Materials, Philadelphia, 1–107.
Powers, J. J. & Moskowitz, H. R. (1976). *Correlating sensory objective measurements—New methods for answering old problems*, ASTM STP 594, American Society for Testing and Materials, Philadelphia, 1–134.
Teranishi, R., Hornstein, I., Issenberg, P. & Wick, E. (1971). *Flavour research: Principles and techniques*. Marcel Dekker, New York.
Van Buren, J. P., Steinkraus, K. It., Hacklar, L. R., El-Rawi, I. & Hard, D. B. (1964). Indexes of protein quality in dried soymilks. *J. Agricultural Food Chemistry*, 524–8.