Development of Models for Predicting the Yield and Quality of Soymilk

T. Y. Tunde Akintunde and B. O. Akintunde

Department of Mechanical Engineering, the Polytechnic, Ibadan
Federal College of Agriculture, PMB 5029 Moor Plantation, Ibadan, Nigeria

Abstract

Models were developed to predict the yield and quality of soymilk, one of soybean products. The quality characteristics investigated were total solids, protein content and fat content. The processing parameters considered were Amount of water added during grinding per Kg of dry seed, A_w; Blanching time, B_T and Heating time, H_T.

The models developed had coefficient of determination ranging from 0.78 to 0.99. Predicted values of the dependent variables compared quite well with the observed values when plotted against the independent variables. The predicted coefficients were also statistically significant ($P < 0.05$). Results showed that the yield and quality characteristics were affected by all the processing parameters. Hence, the production process must be effectively monitored to process soymilk of high yield and quality.

Introduction

Soymilk, a liquid extract is one of soybean products. It is rich in essential mineral salts, fats, carbohydrates and vitamins (Jain, 1985). It is a beverage that offers both refreshment and nutrition and can be labelled as a healthy food because of its composition. It compares favourably with cow milk in properties and can be used in place of cow milk in any recipe where milk is needed (Jain, 1985; Mayhew and Penny, 1988). Generally, soymilk has total solids of 8-10%, protein content of about 3.6%, fat 2.0%, carbohydrate 2.9% and ash 0.5% (Liu, 1997).

Soymilk is a better protein supplement for Nigerians than other soybean products because when used to fortify or supplement traditional foods, large quantities of soymilk do not adversely change the traditional taste of Nigerian dishes. Research carried out on soymilk reveals that it helps growth and development (Bisaliah, 1986). Ogundipe *et al.*, (1989) reported a research carried out in Kersey's Children's Home (KHC) in Ogbomosho, Oyo State where soymilk was used in the diet for restoring malnourished children to health. Chou (1983) also observed that children placed on a formular with soymilk, egg yolk, bone meal and millet had excellent utilisation of the formulae, excellent growth response and no digestive problems. Bisaliah (1986) reported that infants fed on soymilk are free from rickets.

Proper processing of soybeans into soymilk is very important because soybean contains some undesirable properties which include the presence of trypsin inhibitors and lipoxygenase enzymes. These disadvantages can be overcome by proper cooking (Blanching) and hydration (Soaking) of soybeans because it deactivates the enzyme system responsible for the odour (Nelson *et al.*, 1987). Boiling, the application of wet heat loosens soybean seed to ease dehusking and tenderises bean cells. The degree of milling influences digestibility and palatability (Liu, 1997). Boiling whole beans in water for 20 minutes also deactivates the enzyme system and most of trypsin inhibitors (Weingartner, 1987). Blanching also enriches soymilk because if soybean are properly blanched, half of the protein remains soluble in the liquid extract and will not separate with the residue after filtration. However, long blanching times should be avoided in the final soymilk product (Nelson *et al.* 1987). Shi and Ren (1983) observed that heat treatment apparently helps to stabilise soymilk emulsion. The protein molecules unfold and the hydrophobic regions located on the inside become exposed to the outside when soymilk is heated. In the presence of soylipids, the stability of the soymilk

Table1. Composition of soymilk, cow milk and human milk

Item/100g	Soymilk	Cow milk	Human milk
Calorie	44	59	62
Water	90.9	88.6	88.2
Protein	3.6	2.9	1.4
Fat	2.0	3.3	3.1
Carbohydrates	2.9	4.5	7.1
Ash	0.5	0.7	0.2
Minerals (mg)			
Calcium	15	100	55
Phosphorus	49	90	25
Sodium	2	36	15
Iron	1.2	0.1	0.2
Vitamins (mg)			
Thiamine (B1)	0.03	0.04	0.02
Riboflavin (B2)	0.02	0.15	0.03
Niacin	0.50	0.20	0.20
Sat fatty acids (%)	40-48	60-70	55.3
Unsat Fatty acids (%)	52-60	30-40	44.7
Cholesterol (mg)	0	9.24-9.9	9.3-18.6

Source: Chens (1989). Preparation of fluid soymilk

emulsion is improved due to increased interaction of proteins with lipids.

Ogundipe *et. al.* (1989) examined different processing methods for the production of soymilk. The method with the highest yield was the one in which soybeans were soaked overnight before blanching or grinding. Both the quality and yield of soymilk are important parameters since it is the production of quality soymilk and not diluted soymilk that will cause soymilk to achieve its aim as a protein supplement. The objective of this paper is to develop models to predict yield and quality attributes of soymilk based on different processing parameters.

Materials and Methods
Experimental Procedure
Soybeans were obtained from the seed store of the International Institute of Tropical Agriculture (IITA). The soybeans were cleaned and stored in a cool place. One kilogram of the soybeans was soaked overnight and the next morning, it was rinsed and boiled with fresh water (blanching) for a time of 20 and 25 minutes. After blanching, the soybeans were rinsed and milled with 3, 4, and 5 litres of hot water respectively into a slurry form. The slurry was filtered and the milk extract was heated from room temperatures to temperature levels of 60, 70 and 80°C. After the soymilk had cooled, it was bottled. Each of the experiments had 3 replicates which gave 54 observations.

Analytical procedure
The yield was measured using graduated cylinders while the total solids were determined using the formula

$$T.S = \frac{W_3 - W_1}{W_2} \; x \; \frac{100}{1}$$

where

W_1 = initial weight of empty moisture can

W_2 = weight of soymilk

W_3 = final weight of moisture can + sample

Other properties of soymilk used to describe its quality were protein and fat content. These properties were determined using standard tests recommended by AOAC (Association of Official Analytical Chemists). The protein level was determined using the Automated Method (Macrokjeldahl method) while the Crude Fat content was determined using the Automated method (Soxtect System HT2).

Development of Models
Models were established in order to optimise the production process by using the Statistical Analysis System Program. Multiple Regression was used to obtain the estimates of the equation parameters, the analysis of variance and regression coefficient.

The dependent variables were yield (YC) and other quality characteristics namely Total solids (TS), Protein Content (PC) and Fat Content (FC). The independent variables or processing parameters due to the method of processing are Blanching time (B_T), amount of water added during grinding per kilogram of dry seed (A_w) and the temperature to which the soymilk extract is heated (H_T). The models were developed using linear and quadratic functions by regression (SAS, 1996) to determine the equation with the highest R^2 which indicated a higher regression between dependent and independent variables. Different plots of data were made between the independent and dependent variables to observe the trend and obtain possible equations. The dependent variables were plotted against the predicted data to check the predictive ability of the models.

Results and Discussion

The following models were selected as the best for yield and quality attributes.

$$YC = Y_1A_w + Y_2B_T + Y_3H_T + Y_4A_wB_T + Y_5A_wH_T + Y_6B_TH_T + Y_7A_w^2 + Y_8H_T^2 + Y_9 \quad ......(1)$$

$$TS = T_1A_w + T_2B_T + T_3H_T + T_4A_wB_T +$$
$$T_5A_wB_T T_6A_wB_T + T_7A_wB_T + T_8H_T^2 + T_9 ....(2)$$

$$PC = P_1A_w + P_2B_T + P_3H_T + P_4A_wB_T + P_5A_wB_T + P_6A_wB_T + P_7A_wB_T + P_8H_T^2 + P_9 ....(3)$$

$$FC = F_1A_w + F_2B_T + F_3H_T + F_4A_wB_T + F_5A_wB_T F_6 + A_wB_T + F_7A_wB_T + F_8H_T^2 + F_9 ....(4)$$

Where Y_1, T_1, P_1 and F_1 are all constants.

YC = Yield (ml)

TS = Total solids (%)

PC = Protein content (%)

FC = Fat content (%)

A_w = Amount of water added during grinding/kg of seed (litres)

B_T = Blanching time (mins)

H_T = Heating time (mins)

The coefficient of the models are indicated in **table 2**. The fitted models had a coefficient of determination R^2 ranging from 0.78 to 0.99 (**table 2**) which is considered good for biological materials. The predicted values of the dependent variables (YC, TS, PC and FC) plotted against the independent variables (A_w, B_T and H_T) compare quite well with the observed values (**Fig 1-4**). All the prediction coefficients are statistically significant at P<0.05.

Yield: The model for yield is
$$YC = 1394.61A_w - 13.663B_T - 2.872H_T + 6.23A_wB_T + 0.183A_wH_T - 0.214H_TB_T - 132.42A_w^2 + 0.0108H_T^2 - 2002.55 \quad ......(5)$$

All the processing parameters (A_w, B_T and H_T) had a contribution to the yield obtained. From equation (5) the yield increases with A_w (amount of water added during grinding) but decreases with H_T (heating time) and B_T (Blanching time). The yield also has a quadratic relationship with A_w which signifies that there is a minimum point. The yield increases with increase in A_w when the optimum value of 5.3 litres has been

Table 2. Coefficient of models

Dependent variable	Yield		Total Solids		Protein content		Fat content	
R^2	0.99		0.96		0.78		0.96	
	Y_1	1394.61	T_1	-4.5	P_1	-311	F_1	-1.65
	Y_2	-13.663	T_2	-0.843	P_2	0.194	F_2	-0.056
	Y_3	-2.872	T_3	-0.623	P_3	-0.065	F_3	0.00044
	Y_4	6.23	T_4	0.153	P_4	-0.012	F_4	0.0348
	Y_5	0.183	T_5	0.024	P_5	0.0095	F_5	-0.0044
	Y_6	-0.214	T_6	0.0047	P_6	-0.026	F_6	-0.00012
	Y_7	-132.42	T_7	0.11	P_7	0.324	F_7	0.146
	Y_8	0.0108	T_8	0.0033	P_8	0.00072	F_8	0.000092
	Y_9	-2002.55	T_9	42.71	P_9	7.3	F_9	5.48

Fig 1. Effect of amount of water added on soymilk yield after blanching for 20 minutes
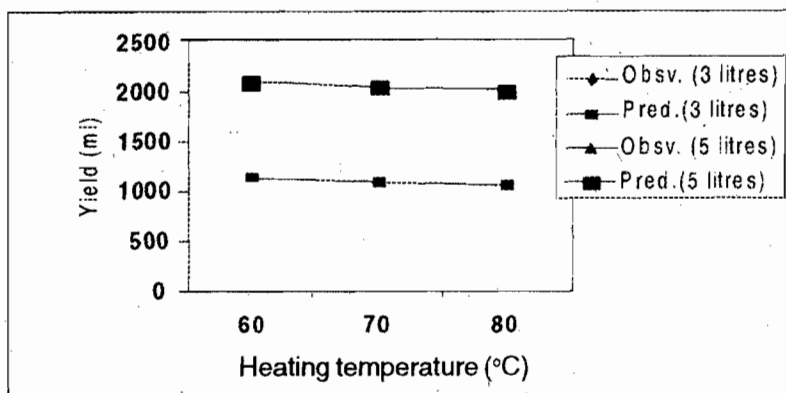

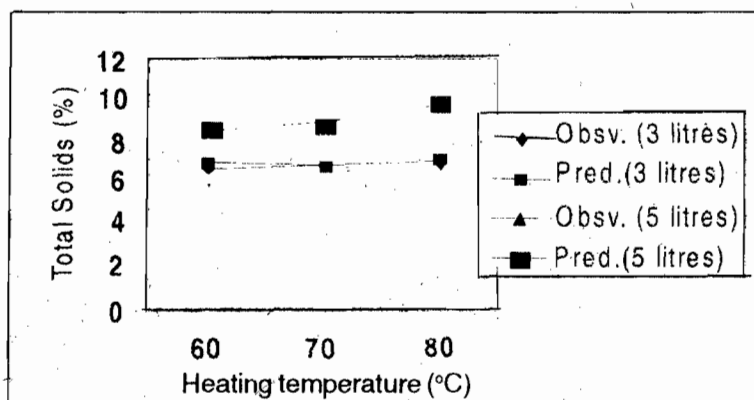**Fig 2.** Effect of heating temperature on total solids of soymilk obtained from a blanching time of 20 minutes

Fig 3. Effect of heating temperature on the protein content of soymilk from single fold of filter cloth and blanching time of 20 minutes
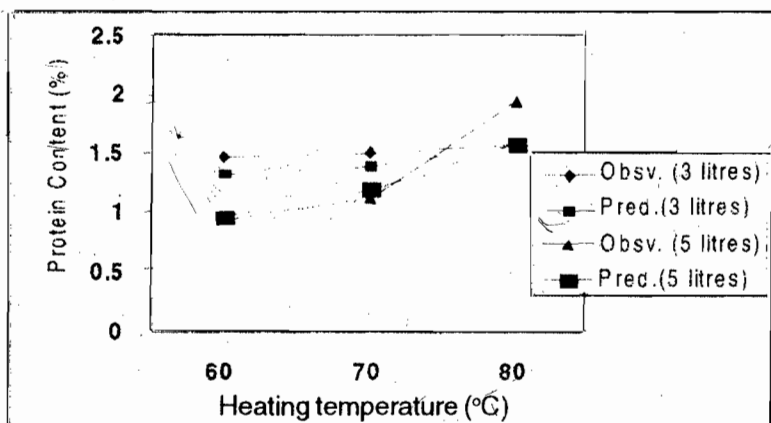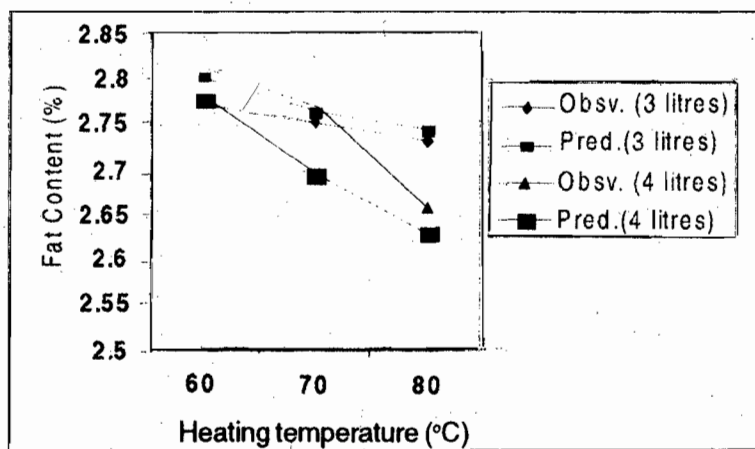

Fig 4. Effect of heating temperature on fat content of soymilk obtained from single fold of filter cloth and blanching time of 25 minutes

reached. This agrees with the fact that an increase in water added to form slurry increases the ability to wash the suspended solids through the filter cloth. Therefore the processor must know that low amounts of water added during milling should be avoided since it does not give optimum yield. H_T also has a quadratic relationship but this relationship signifies that there is a maximum value of $91.68°C$ for H_T. The yield will increase until an optimum value of - for H_T is obtained beyond which it would start to decrease. However since the soymilk has to be heated to temperatures relatively high above room temperature in order to cook the soymilk which increases its palatability, too high temperatures have to be avoided since it decreases the yield. This is due to the evaporation of soymilk at high temperatures. This is very important to the processor because he has to strike a balance and use optimum heating times that will properly cooked soymilk without significant decrease in yield.

Total Solids

The contribution of A_w, B_T and H_T are shown in equation 6.

$$TS = 42.71 - 4.5A_w - 0.843B_T - 0.623H_T + 0.153A_wB_T + 0.024A_wH_T + 0.0047B_TH_T + 0.11A_w^2 + 0.0033H_T^2 \quad \ldots\ldots\ldots(6)$$

A_w, B_T and H_T all contribute negatively to the total solids which implies that an increase in these parameters will cause a decrease in total solids in the soymilk. A_w and H_T have a quadratic relationship with total solids such that both A_w and H_T have a decreasing effect on total solids until an optimum value is reached and the effect becomes increasing.

The total solids will decrease with increase in A_w until an optimum value of 3.2 litres is reached after which the total solids will start to increase. This is because at low A_w, the slurry will be very thick and this increase the occurrence of clogging of the sieve holes which invariably reduces the total solids in the filtrate. However, at high A_w, the occurrence of clogged holes is reduced and thus suspended solids in the slurry are able to wash through the filter holes into the filtrate thus increasing total solids. Therefore A_w should not be less than 3.2 litres or else the processor will not achieve maximum output.

The H_T has a similar effect on total solids. The total solids will decrease until an optimum value of 73°C for H_T is obtained beyond which the total solids will begin to increase. This is very important to the processor since it is an indication that the stability of the soymilk emulsion is achieved at high temperatures and not low temperatures. Also at high H_T, liquid portions of the soymilk extract are vaporised quicker which increases the percentage of solids in the heated soymilk relative to the yield obtained. This is important to the processor to know that the best soymilk with high total solids is obtained with high amounts of water added during grinding and high values of heating times.

Protein content

The protein content of soymilk is very important if it is to fulfil the purpose of supplementing the protein intake of people. The equation for protein content is $PC=7.3- 3.11A_w + 0.194B_T - 0.065H_T- 0.012A_wB_T + 0.0095\ A_wH_T - 0.026B_TH_T+0.32A_w^2 +0.00072H_T^2$ ....(7)

The coefficient of the model indicates that increasing B_T increases the protein content of soymilk. This is because blanching soybean before grinding denatures the protein and makes it more soluble and digestible. This agrees with the findings of Nelson *et al.* (1987) that blanching enriches soymilk because half of the soyprotein remain soluble and does not separate with the residue after filtration.

From the model coefficients in **Table 2**, an increase in A_w will cause a decrease in protein content until an optimum value of 4.47 litres is reached, beyond which, the protein content will start to increase. This is because the A_w will wash the soluble protein through the filter cloth into filtrate while low amounts of A_w will result in clogging of filter cloth. The protein content obtained with an increase in H_T decreases until H_T is 53.9 mins and beyond this value increases (equation 7) until it reaches the temperature (approximately 90°C) at which it starts to coagulate. This implies that for high values of protein content, the H_T should be increased. This is similar to the observations of Shi and Ren (1993) that heat treatment causes

the protein molecules to unfold in the presence of soylipids which improves the stability of soymilk emulsion. It is therefore necessary for the processor to know that protein content is affected by the processing parameters and adequate monitoring of the production process should be done if soymilk is to be used especially as a protein supplement.

Fat content

The three processing parameters, A_w, H_T and B_T all affect the fat content. The equation for fat content is $FC=5.48- 1.65A_w-0.056B_T+ 0.00044H_T+ 0.0348A_wB_T-0.0044A_wH_T -0.00012B_TH_T + 0.146A_w^2 +0.000092B_T^2$ ....(8)

An increase in A_w and B_T causes an increase in fat content while an increase in H_T decreases the fat content. B_T has an indirect effect on the fat content in the slurry because heating the seeds before grinding causes an increase in fluidity of oil in oil cells such that oil will flow more readily when the oil cells are broken down during grinding (Ward 1976).

The quadratic relationship between fat content and A_w from Equation 8 indicates that the minimum A_w required for an increase in fat is 1.63 litres. An increase in A_w beyond this value will increase the fat content of soymilk produced. This is because an increase in A_w will help wash the fat-soluble nutrients into the slurry and also reduce the clogging of filter holes. The low value of optimal A_w is because the liberated oil/fat are less viscous and more fluid in nature because of the blanching treatment and therefore less water is needed to help wash the oil through the filter cloth into filtrate when compared with other solid based quality characteristics. This is important to the processor since it indicates that the high values of A_w needed for other quality characteristics (i.e. protein content) also have positive effects on fat content and not be a waste of input.

The equation for fat content (equation 8) indicates that there is a maximum point for H_T. This implies that at constant A_w and B_T, the fat content will increase with H_T until 6.38°C and then start decreasing. This is important to the processor because for optimum fat

content, low values of H_T are required so as not to waste time and money in heating the soymilk. However the processor must realise that since an increase in H_T increases protein content, a balance for the value of H_T must be struck between the protein content and fat content to obtain optimum levels of both quality attributes.

Conclusion

The developed models predicted the yield, total solids, protein content and fat content effectively. The three main processing parameters had a significant effect on the yield and quality of soymilk. As a result, the parameters need to be monitored closely during production of soymilk in order to produce soymilk of optimum yield and quality.

References

Bisaliah, S. 1986. Soybean development in India. CGPRT Number 5, UN/ESCAP CGPRT center.

Chen, S. 1989 Preparation of fluid soymilk. In Proceedings of the World Congress on Vegetable protein Utilisation in Human Foods and Animal Feedstuffs Edited by Applewhite, T. N. American Oil Chemists Society, Champaign, Illinois Pp 341-351.

Chou, C. 1983 Studies on the use of Soyfood infant feeding in China and development of Formula 5410. Food Nutr. Bull; 4. 45-52.

Jain, J. D. 1985 Soybean; its value of dietics, cultivation and uses. International Books and Periodicals Supply Service 24-b/5 Desh Bandu, Gupta Road, New Delhi -110005.

Liu, K. 1997 Soybean chemistry, technology ad Utilisation. Chapman and Hall 115 fifth Avenue, New York, NY 10003 Pp.

Mayhew, S and Penny, A. 1988. Tropical and sub-tropical foods. Macmillian Publishers Ltd. London and Basingstoke.

Nelson, A. I., Wei, L. S. and Weingartner, K. E. 1987. Home and Village preparation of soy products. In Soybean for the Tropics. Edited by Singh, S. R., Rachie, K. O., Dashiell, K. E., John Wiley and Sons Ltd. Pp.

Ogundipe, H. O., Dashiell, K. E., and Osho, S. M. 1989. Soymilk yield and quality as affected by soybean varieties and processing techniques. Tropical Grain Legume Bulletin Number 36, International Institute of Tropical Agriculture (IITA) Pp 12-14.

SAS Institute Release 6.12 (1996) SAS User's Guide; Statistics, SAS Institute, Inc. Cary NC.

Shi, T. G. and Ren, L. 1993. Soyfood Technology (Chinese). China's Light Industry Publisher, Beijing, China.

Ward, J. A. 1976. High oil content seeds in continuous screw presses. Journal of American Oil Chemist's Society 53 (6): 261-264.

Weingartner, E K. 1987. Processing, Nutrition and Utilisation of Soybeans. In Soybean for the Tropics. Edited by Singh, S. R. Rachie, K. O. and Dashiell, K. E. John Wiley and Sons Ltd. Pp.