Model development for yield and quality attributes of soymilk

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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 model 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.

Keywords: blanching time, heating time, total solids, yield, protein content, fat content

Introduction

Soymilk, a liquid extract is one of soybean products. It is rich in essential mineral salts, fats, carbohydrates and vitamins (Jain, 1998). It is a beverage that offers both refreshment and nutrition and can be labeled as a healthy food because of its composition. It compares favourably with cow milk in properties (Table 1) and can be used in place of cow milk in any recipe where milk is needed (Jain, 1998; Mayhew and Penny, 1998). 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, 2005).

Research carried out on soymilk reveals that it helps growth and development (Bisaliah, 1996). Ogundipe *et al.* (2001) 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 (1993) also observed that children placed on a formula with soymilk, egg yolk, bone meal and millet had excellent utilization of the formulae, excellent growth response and no digestive problems. Bisaliah (1996) 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 dehydration (Soaking) of soybeans because it deactivates the enzyme system responsible for the odour (Nelson *et al.*, 1997). Boiling, the application of wet heat loosens soybean seed to ease dehusking and tenderizes bean cells. The degree of milling influences digestibility and palatability (Liu, 2005). Boiling whole beans in water for 20 minutes also deactivates the enzyme system and most of trypsin inhibitors (Weingartner, 1996). Blanching also enriches soymilk because if soybeans 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.*, 1997). Shi and Ren (2000) observed that heat treatment apparently helps to stabilize 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 emulsion is improved due to increased interaction of proteins with lipids.

Ogundipe *et al.* (2001) 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

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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 local market. The soybeans were cleaned and stored in a cool place. One kilogram of the soybean was soaked

Table 1. Composition of soymilk, cow milk and human milk

Item/100g	Soymilk	Cow milk	Human milk
Calorie	44	59	62
Water	90.0	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)			
Thiamin (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 (%)	40-80	60-70	55.3
Unsat. Fatty acids(%)	52-60	30-40	44.7
Cholesterol (mg)	0	9.24-9.9	9.3-18.6

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 has 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

$$\text{T.S.} = \frac{W3 - W1}{W2} \times \frac{100}{1}$$

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 quantity 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) while the Crude Fat content was determined using the Automated method (Soxhlet System HT2).

Development of models

Models were established in order to optimize 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 quadric functions by regression (SAS, 1996) to determine the equation with the highest R^2 which indicated a higher regression

Table 2. Coefficient of models

Dependent Variable	Yield		Total Solids		Protein Content		Fat Content	
R^2	0.99		0.96		0.78		0.96	
	Y1	1394.61	T1	-4.5	P1	-311	F1	-1.65
	Y2	-13.663	T2	-0.843	P2	0.194	F2	-0.056
	Y3	-2.872	T3	-0.623	P3	-0.065	F3	0.00044
	Y4	6.23	T4	0.153	P4	-0.012	F4	0.0348
	Y5	0.183	T5	0.024	P5	0.0095	F5	-0.0044
	Y6	-0.214	T6	0.0047	P6	-0.026	F6	-0.00012
	Y7	-132.42	T7	0.11	P7	0.324	F7	0.146
	Y8	0.0108	T8	0.0033	P8	0.00072	F8	0.000092
	Y9	-2002.55	T9	42.71	P9	7.3	F9	5.48

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.

Result and Discussion

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

$$YC = Y_1 A_w + Y_2 B_T + Y_3 H_T + Y_{4AW} B_T + Y_5 A_W H_T + Y_6 B_T H_T + Y_7 Aw^2 + Y_8 H_T^2 + Y_9 \text{--------- (1)}$$

$$TS = T_1 A_w + T_2 B_T + T_3 H_T + T_4 A_w B_T + T_5 A_w B_T T_6 A_w B_T + T_7 A_w B_T + T_8 H_T^2 + T_9 \text{-------- (2)}$$

$$PC = P_1 A_w + P_2 B_T + P_3 H_T + P_4 A_w B_{T+} P_5 A_w B_T + P_6 A_W B_T + P_7 A_w B_T + P_8 H_T^2 + P_9 \text{----- (3)}$$

$$FC = F_1 A_W + F_2 B_T + F_3 H_T + F_4 A_w B_T + F_5 A_W B_T F_6 + A_W B_T + F_7 A_w B_T + F_8 H_T^2 + F_9 \text{------ (4)}$$

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 (minutes)

H_T = Heating time (minutes)

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. All the prediction coefficients are statistically significant at P<0.05.

Yield: The model for yield is

$$YC = 1394.61 A_W - 13.663 B_T - 2.872 H_T + 6.23 A_W B_T + 0.183 A_W H_T - 0.214 H_T B_T - 132.42 A_W^2 + 0.0108 H_T^2 - 2002.5 \quad \text{--------(5)}$$

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 increase with increase in Aw when the optimum value of 5.3 litres has been 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 signifies that there is a maximum value of 91.68 ℃ 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.

$$TS = 42.71 - 4.5 A_w - 0.843 B_T - 0.623 H_T + 0.153 A_W B_T + 0.024 A_W H_T + 0.0047 B_T H_T +$$

$$0.11 A_W^2 + 0.0033 H_T^2 \text{ ---------- (6)}$$

A_w, B_T 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 increases 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 vaporized quicker which increases the percentage of solids in the heat 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 fulfill the purpose of supplementing the protein intake of people. The equation for protein content is:

$$PC = 7.3 - 3.11 A_w + 0.194 B_T - 0.065 H_T - 0.012 A_W B_T + 0.0095 A_W H_T - 0.026 B_T H_T + 0.32 A_w^2 + 0.00072 H_T^2 \quad ----------- (7)$$

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 finding of Nelson *et al*. (1997) 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 minutes 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 value of protein content, the H_T should be increased. This is similar to the observations of Shi and Ren (2000) 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:

$$FC = 5.48 - 1.65 A_W - 0.056 B_T + 0.00044 H_T + 0.0348 A_W B_T - 0.0044 A_W H_T - 0.00012 B_T H_T + 0.146 A_W^2 + 0.000092 B_T^2 \quad ------(8)$$

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 1990).

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. protien 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 realize that since an increase in 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.

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