Ghana J. Sci. **44** (2004), 11-18

PROCESS TECHNOLOGY FOR REFINING CRUDE SOYBEAN OIL – A PRODUCT FROM SOYCAKE MEAL PRODUCTION IN GHANA

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Abstract

Selective optimization of process.parameters for refining crude soybean oil was carried out to determine and specify such process parameters as temperature, concentration of reactants, and process duration for adoption in commercial processing. The procedure adopted for the work considered technical and material resources available, local availability of process equipment for commercial production, cost involved, and the target beneficiaries. The aim was to add value to the crude oil to increase incomes for the small-scale producers. The process parameters adopted for transfer included 0.1% v/v 75 % phosphoric acid at 80 ± 5 °C, 2 % v/v water at 65 ± 5 °C and 30 per cent excess caustic for neutralization. A refined oil yield of 83.3 per cent was recorded. Results of quality assessment of the final laboratory refined oil compared favourably with Ghana Standards Board's specification for edible soybean oil.

Résumé

MENSAH, B. & AGGEY, M.: *Technologie du procédé pour le raffinage d'huile brute de la graine de soja – le sous-produit de la production d'alimentation de la farine de soja à Accra.* Dans ce travail, l'optimisation sélective des paramètres du procédé pour le raffinage d'huile brute de la graine de soja s'était déroulée pour déterminer et spécifier tels paramètres du procédé que la température, la concentration des reactants et la durée du procédé pour être adopté dans le traitement commercial. La procédure adoptée pour le travail prenait en considération les resources techniques et matérielles disponibles, la disponibilité locale d'équipment du procédé pour la production commerciale, le coût de production et les bénéficiaires cibles. Le but était d'ajouter de la valeur à l'huile brute en vue d'augmenter les revenus pour les producteurs peu importants. Les paramètres du procédé adoptés pour le transfert comprennent 0.1 % v/v 75 % d'acide phosphorique à 80 ± 5 °C, 2 % v/v d'eau à 65 ± 5 °C et 30 pour cent excès de caustique pour la neutralisation. Un rendement d'huile raffinée de 83.3 pour cent était réalisé. Les résultats de l'évaluation de qualité de l' huile finale raffinée au laboratoire se comparaient favorablement avec la spécification de Ghana Standards Board pour huile comestible de la graine de soja.

Introduction

As a means of increasing per capita protein intake, the Ghana government has promoted cultivation of soybean since 1971. However, cultivation by private farmers only began in 1990. From then onwards, the annual production of soybean rose to 5000 tonnes per annum in 1994. Owing to initial marketing difficulties, production fell to 2500 tonnes in 1996 (ICOUR, 1996). However, with the introduction of soycake into the poultry and animal feed industry, soybean consumption increased. More than 70 per cent of the soybean is processed into meal for poultry and animal feed each year, yielding substantial amount of crude oil.

The preparation of marketable soybean oil for human consumption from crude soybean oil requires a series of processes known collectively

as 'refining'. Crude soybean contains several fatty compounds other than triglycerides and other impurities. These include phospholipids and free fatty acids. Production of high quality finished oils requires the removal of as much of these impurities as possible through the refining process. The refining steps include degumming, alkali refining, bleaching, hydrogenation, and deodorization. Several alternative technologies are available for application in refining vegetable oils such as soybean oil.

For each particular oil, the extent of application of the refining process depends on the nature of the crude and the quality of oil required or acceptable on the target market. Degumming removes phospholipids in the oil to prevent the separation and settling of gums in the oil and to reduce oil losses in subsequent phases of refining. In degumming, the crude oil is warmed and water is added and thoroughly mixed for a period of time. Centrifuging or settling separates the gums formed. An aid to the removal of phospholipids is to acidify the oil with phosphoric acid before adding water.

Alkali is refined to remove free fatty acids from the oil. The free fatty acids are a problem in finished foods because they promote foaming and lower the smoke point of heated oil. Alkali refining also removes residual phospholipids not removed by degumming. The normal procedure is to add alkali (sodium hydroxide is most commonly used, though the carbonate can also be used) to the oil to convert the free fatty acid to soaps and to remove the soap stock by centrifuging or settling.

The free fatty acid content of degummed oil is used to calculate the amount of alkali needed to neutralize the oil. Excess alkali is usually used, the amount depending on other impurities in the oil. The appropriate amount of sodium hydroxide (16-18 Baume) is mixed with degummed oil for 5 to 10 min; the mixture is then heated to 75° C and the resulting soap stock formed separated by centrifuging. The oil is then washed at about 92 ±2 °C with up to 15 per cent water and centrifuged again to remove residual soap stocks. Bleaching removes the yellow carotenoid pigments and green chlorophyll of the oil. It also removes other impurities such as residual phospholipids, traces of soap stocks, and peroxides.

The extent of bleaching depends on the market requirements; some prefer almost water-clear appearance whilst somewhat darker oils may be acceptable in other markets. In bleaching, the oil is treated with natural bleaching earths such as Fuller's Earth, acid-activated clays composed mainly of bentonites, or activated carbon. About 0.3 to 1 per cent of the bleaching agent is mixed with the oil and the mixture heated to 105-110 °C under vacuum for varying periods of time. The slurry is then cooled and filtered.

Deodorization removes unwanted odours and flavour substances such as aldehydes and ketones, resulting in a bland finished product. Other compounds including free fatty acids are also removed. These compounds are removed from fats and oils by steam-stripping under vacuum and at between 170 and 250 °C. The time required to deodorize the oil depends on the steam pressure, temperature of the steam, and the amount of steam used for stripping. Deodorization may be applied as a batch, semi-continuous, or as a continuous process. After stripping, the oil is cooled under vacuum to prevent oxidation. The cooled oil from the deodorizer is then filtered and stored to prevent further oxidation.

The objective of the study was to develop a process for refining crude soybean oil, a by-product from local soycake production.

Experimental

Source of crude soybean oil

Crude soybean oil was collected from FATECO Ltd, a small-scale soycake-producing company at Pokoase near Accra, Ghana.

Crude soybean oil refining

Fig. 1 and 2 show the processes for refining crude soybean oil.

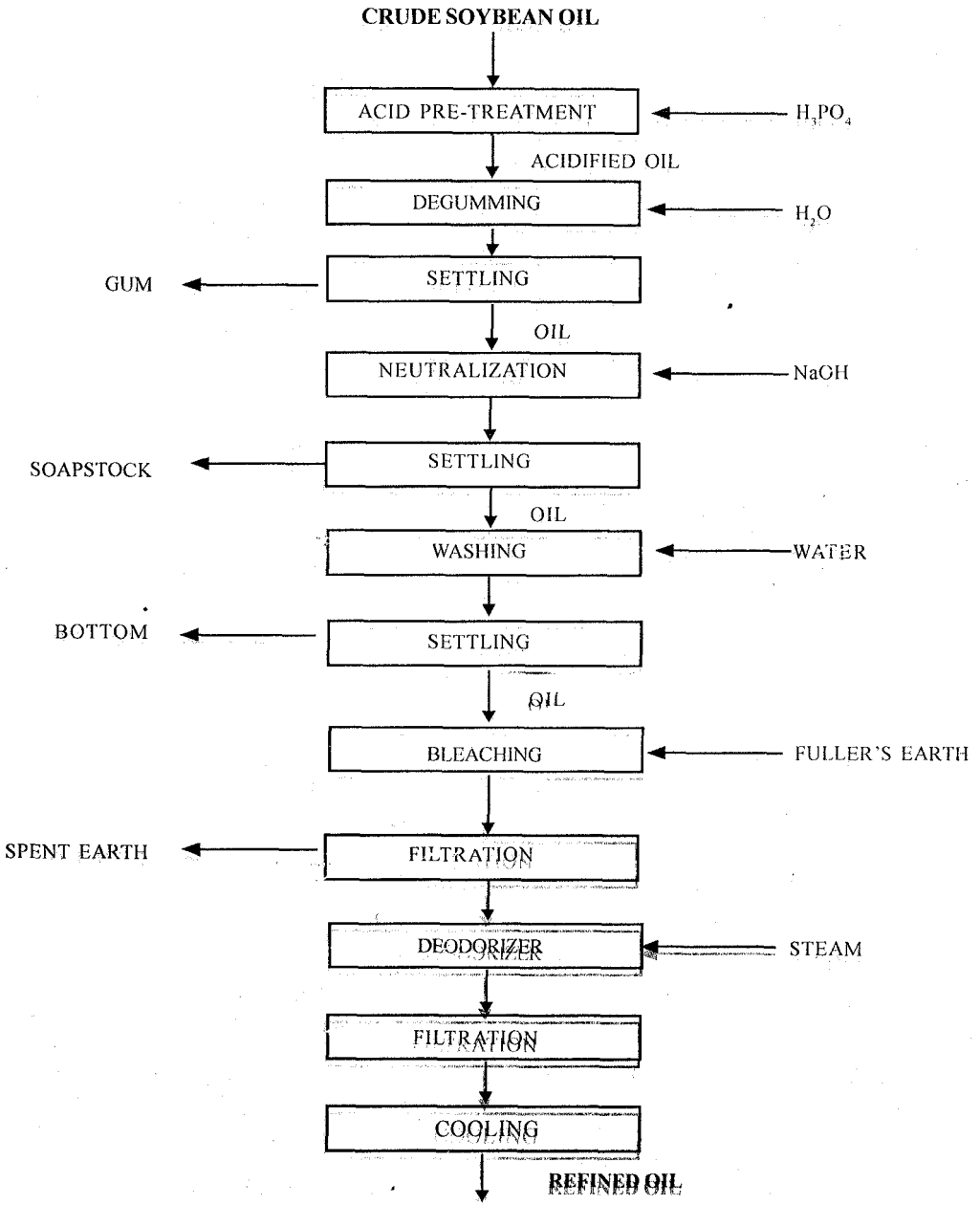

Fig. 1. Flow chart-refining process for crude soybean.

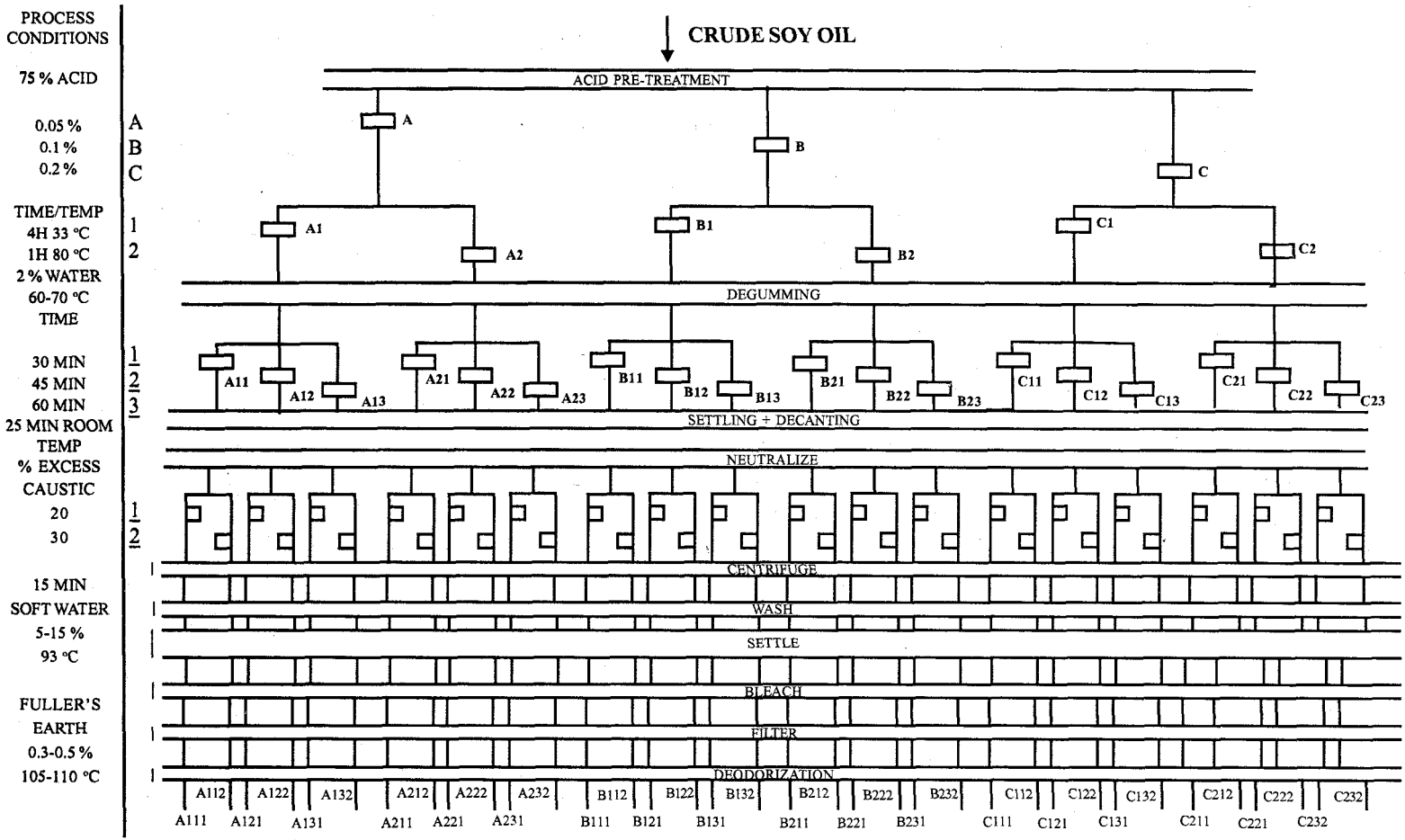

Fig. 2. Optimization scheme for soybean oil refining.

Acid pre-treatment. An initial sample of 50 l of crude oil was composed from batches of 10 l of crude from five oil storage tanks. Out of this, a contract sample of 18 l was taken and shared into 6-l sub-samples designated A, B and C.

Sub-sample A was divided into two equal portions of 3 l each, designated as A_1 and A_2. Sample A_1 was treated with 1.5 ml of 75 per cent phosphoric acid equivalent to 0.05 per cent v/v crude oil at room temperature with continuous stirring for 4 h.

Sample A_2 was heated on a hot plate to 80 ± 5 °C and treated with 1.5 ml of 75 per cent phosphoric acid and stirred continuously for 1 h. The above procedures were repeated for the oil sub-samples B and C (Fig. 2). For sub-sample B, 3 ml phosphoric acid equivalent to 0.1 per cent v/v crude oil was used and 6 ml acid equivalent to 0.2 per cent v/v was used on sub-sample C. A set of six samples A_1, A_2, B_1, B_2, C_1 and C_2 resulted from the acid treatment operations.

Degumming. Each acid-treated sample was further shared into three equal portions (about 1 l each) and treated with 2 per cent v/v water. Samples A_{11}, A_{21}, B_{11}, B_{21}, C_{11}, and C_{21} (Fig. 2) were subsequently maintained at 65 ± 5 ° C with stirring for 30 min, whilst samples A_{12}, A_{22}, B_{12}, B_{22}, C_{12}, and C_{22} were stirred for 45 min at 65 ± 5 °C and samples A_{13}, A_{23}, B_{13}, B_{23}, C_{13}, and C_{23} were stirred for 60 min at 65 ±5 °C. Each mixture was then allowed to settle and the clear oil decanted. A set of 18 samples resulted from degumming. Phosphorus and free fatty acid contents of each degummed oil were determined.

Alkali refining (neutralization). Depending on the free fatty acid (FFA) content of the degummed oil, an amount of NaOH solution (160.58 gm/l) required to neutralize the free fatty acid was calculated. Excess amounts of the NaOH solution, ranging from 10 to 30 per cent of the calculated value, were used to neutralize various samples of the degummed oil.

For neutralization, the required amount of the NaOH solution was mixed with the oil sample and stirred for 35 min at room temperature (29 ± 2 °C). Each mixture was then heated to 92 ± 2 °C, and 10 per cent v/v water on degummed oil sample was added with stirring for 15 min. Each mixture was allowed to settle and the clear neutralized oil decanted. The FFA of the neutralized oil samples were determined.

Bleaching. Fuller's Earth was used for bleaching. Each sample of neutralized oil was heated to 105 ± 2 °C and 1 per cent w/v Fuller's Earth was added with stirring for 10 min under vacuum. Each mixture was cooled under vacuum and then filtered.

Deodorization. Samples of the bleached oil were deodorized by steam stripping. The bleached oil was heated under vacuum (680-610 mm Hg) to 115 °C in a heating mantle. Steam at 25 psi was passed through the oil and its temperature raised and kept at 160-180 °C. Stripping ranged between 2 and 3½ h. After stripping, the oil was dried under vacuum at 120 ± 5 °C for 1 h and then cooled under vacuum till the temperature dropped to below 100 °C.

Methods of analysis

Standard methods (Welcher, 1963) were used to determine moisture, insoluble impurities, FFA, and phosphorus contents. The parameters for assessing the quality of the final refined oil-iodine value, peroxide value, refractive index, specific gravity, soap content, and saponification value were determined by standard methods (AOAC, 1984) at Ghana Standards Board.

Three samples of 2.7 kg each of crude oil were processed to the deodorization stage using the optimal parameters, and each of the refined oil product was weighed to estimate the yield (Y) as follows:

$Y = (\text{weight of refined oil/weight of crude}) \times 100\ \%$

Results and discussion

Table 1 shows the FFA, moisture and impurity contents of the crude soybean oil used. The moisture content of 0.13 per cent was low, because in soycake meal production, the beans are normally roasted for the desired flavour, among others.

TABLE 1
Characteristics of crude oil sample

	Crude oil sample	*Literature values**
FFA (%)	0.46	0.3-0.7
Moisture (%)	0.13	0.3-0.5
Impurities (% m/m)	0.09	-

Literature values from Singh *et al.* (ed.) (1987) *Soybeans for the tropics.* John Wiley & Sons.

Degummed oil

In all, 18 samples of degummed oil were produced from the original contract sample (Fig. 2). Table 2 shows the FFA values and phosphorus contents of the oil samples. The FFA values of the degummed oil samples generally increased from the 'A' group through the 'B' group to the 'C' group. This may be attributed to the increasing quantity of phosphoric acid added to the oil samples in the acid pre-treatment stage. All the FFA values for A and B sample groups were below the reported maximum value of 0.75 per cent (Singh *et al.,* 1987), whilst the C samples showed two higher values above the required maximum of 0.75 per cent.

As a group, the B samples generally had lower residual phosphorus contents (0.004-0.008 %) than those of the A (0.005- 0.067 %) and C (0.005-0.052 %) groups. The relatively high values in the A samples were due to limited removal of phospholipids because of the insufficient phosphoric acid used. The higher values of residual phosphorus in the C samples were ascribed to the increased phosphoric acid used in the acid pre-treatment stage. The phosphorus content of degummed soybean oils is reported to be in the range of 0.001 to 0.005 per cent (Mattil *et al.,* 1964). A maximum phosphorus content of 0.02 per cent has also been reported (Singh *et al.,* 1987). It was further observed that the degummed oil samples in the C group were darker than those in the A and B sample groups.

Using the FFA values and the phosphorus content of the degummed oil as the main criteria for optimizing the degumming process, the B sample group treated with 0.1 per cent phosphoric acid (75 %) was selected for further processing.

Alkali refined oil

Table 3 shows the FFA values for degummed oils refined with 20 and 30 per cent caustic over the calculated amount required to neutralize each oil. Oil samples treated with 20 per cent excess caustic showed high FFA values as compared to the FFA values of samples treated with 30 per cent excess caustic. All the three samples treated with 30 per cent excess caustic showed FFA values within the maximum value of 0.30 per cent. Using the FFA values as the main criteria for optimizing the alkali refining operation, any B sample treated with 30 per cent excess caustic could be selected. Sample B_{22}, with the least FFA value was, therefore, selected. A fresh sample of crude oil was then processed to the deodorization stage, using the B_{22} parameters (Table 4).

Samples of the refined deodorized soybean oil were then taken to the Ghana Standards Board for complete quality assurance tests. Table 5 shows that the quality of the refined oil obtained from the laboratory was satisfactory and within the required standard specification. However, the peroxide value of 26.2 m.e.q./kg of oil exceeded the maximum required level of 10 m.e.q./kg. This can be attributed to leakage of air into the deodorizer during deodorization. The leakage was among the numerous problems met during the process development. From the laboratory trials, the refined oil yield was 83.3 % on the crude.

Conclusion

The laboratory process development for refining crude soybean oil, a by-product from soycake

TABLE 2

Phosphorus and FFA contents of degummed soybean oil

Sample	*% FFA*	*% phosphorus*
A_{11}	0.40	0.005
A_{12}	0.35	0.028
A_{13}	0.42	0.017
A_{21}	0.30	0.067
A_{22}	0.44	-
A_{23}	0.41	-
B_{11}	0.53	0.004
B_{12}	0.52	0.004
B_{13}	0.61	-
B_{21}	0.61	0.007
B_{22}	0.46	0.004
B_{23}	0.46	0.008
C_{11}	0.79	0.022
C_{12}	0.51	0.005
C_{13}	0.67	0.006
C_{21}	1.11	0.007
C_{22}	0.59	0.052
C_{23}	0.67	0.014
Literature values*	0.75 (max.)	0.02 (max.)

* Literature values from Singh *et al.* (1987)

TABLE 4

Selected process parameters adopted for transfer

Operation	*Condition*
Acid pre-treatment	0.1% vol. of phosphoric acid (75 %) per vol. of oil, mix 1 h at 80 ± 5 °C
Degumming	2 % water, mix 45 min at 65 ± 5 °C
Neutralization	30 % excess caustic, mix 25 min at room temperature, wash with 10 % water at 92 ± 2 °C
Bleaching	Bleach under vacuum with 1 % Fuller's Earth for 10 min at 103 ± 2 °C
Deodorization	Oil at 160-180 °C steam at 20 psi, for 3½ h under vacuum

production, yielded 83.3 per cent refined oil on crude. The quality of the refined oil produced was satisfactory by Ghana Standards Board's specifications for edible soybean oil. The selected optimum process parameters indicated in Table 4 formed the basis for transferring the process technology into commercial production.

TABLE 3

FFA contents of alkali-refined oil samples

Sample	*% FFA using 20 % excess caustic*	*% FFA using 30 % excess caustic*	*Standard (%)*
B_{21}	0.42	0.29	
B_{22}	0.46	0.26	30 max.
B_{23}	0.30	0.30	

TABLE 5
Quality assessment of laboratory-refined crude soybean oil

Test conducted	*Refined oil*	*Standard specification**
FFA (%)	0.1	0.3 max.
Saponification value (mg KOH/g oil)	192.9	189-195
Iodine value, Wigs	124	120-143
Peroxide value (m.e.q./kg)	26.2	10 max.
Moisture (%)	-	0.2 max.
Insoluble impurities (%)	nil	0.5 max.
Refractive index	1.468	1.466-1.470
Specific gravity	0.913	0.919-0.925
Soap content (% m/m)	nil	0.005 max.
Phosphorus	Not detected	-

* Source: Ghana Standards Board

Acknowledgement

The authors are indebted to the laboratory staff of Lube Oil (Ghana) Limited and Ghana Standards Board, as well as to Mr A. K. Monney of the CSIR-Institute of Industrial Research for conducting several analyses reported in this paper.

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Received 05 Feb 03; revised 27 Jan 04.