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Chemical and physical characteristics of palm, palm kernel and groundnut oils as affected by degumming

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Three reagents (NaOH, Na_2CO_3 and H_3PO_4) were evaluated for their effectiveness in degumming three crude vegetable oils [palm oil (PO), palm kernel oil (PKO) and groundnut oil (GNO)]. All chemical reagents were prepared at strengths of 0.5, 1, 2 and 5% (w/v) and used in turn for degumming. Degumming effected a remarkable improvement in quality characteristics of the oil samples. Free fatty acids (FFA) were within standard specifications, (0.003–0.04%) and the peroxide values (PV) were very low, (0–1.0 meq/kg). The greatest yield-after-filtration (YAF), 88%, was obtained from 5% NaOH-degummed PKO. Sodium hydroxide was found to be the best degumming reagent from the standpoint of oil samples with least FFA, PV, dynamic viscosity (DV) and greatest YAF. In terms of % colour reduction (CR), H_3PO_4 was most effective in PKO only. Statistical analyses of the three-factor (oil type, degummer type and degummer strength) interactions ($P=0.05$) indicated that the parameters can be graded in order of significance thus: Smoke point > DV > PV > FFA > CR > YAF.

INTRODUCTION

Crude edible vegetable oils contain some extraneous substances (e.g. proteinaceous matter) which lower smoke point while others cause objectionable colour development (Weiss, 1983). Phosphatides (glycerophosphatides) are naturally-occurring emulsifiers which bind oil molecules together leading to increased viscosity, and refining and/or flow losses (Chikoti, 1988). These must be removed from the oils via a series of steps and processes which are together called refining. Refining is done to improve shelflife and nutritive status of the resultant oils (Haraldsson, 1983; Ihekoronye & Ngoddy, 1985).

Degumming is the first stage in refining, and it is used to precipitate metal salts (Weidermann, 1981; Cornelius, 1983) and other hydratable phosphatides and mucilagenous materials likely to cause the oil to develop flavours and odours (Asiedu, 1989), and induces neutralization (Mwale, 1987). Degumming basically involves addition of a chemical reagent to a crude oil maintained at 85–90°C and stirred for 20 min, or maintained at 50–70°C and stirred for 30 min, cooling to 40°C and separation into oil and impurity stock prior to neutralization (List *et al.*, 1981; Cornelius, 1983; Haraldsson, 1983).

Whilst many studies of degumming of soyabean, sunflower and even carona oils have been extensively reported (Carr, 1976; Racicot & Handel, 1983; Rushing, 1983; Al-Kahtani *et al.*, 1984; Nash *et al.*, 1984: Sharma *et al.*, 1985; Smiles *et al.*, 1988; Jung *et al.*, 1989), there is little information about degumming effectiveness in Nigerian palm, palm kernel or groundnut oils.

This investigation therefore assesses the effects of three selected chemical reagents by several physical parameters (colour, smoke point, dynamic viscosity and yield-after-filtration) as well as by chemical parameters (free fatty acids and peroxide values) which indicate hydrolytic or oxidative rancidities (Henick, 1978) of palm, palm kernel and groundnut oils.

MATERIALS AND METHODS

Preparation of oil samples

Crude oil samples were obtained as follows: groundnut oil (GNO) was obtained from a local processor in Kano, Northern Nigeria, palm oil (PO) was extracted by a local method from freshly harvested fruits, while palm kernel oil (PKO) was extracted via the traditional dry-heat rendering method according to Banigo *et al.* (1977). Reference samples were commercially refined

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grades from the following sources: GNO (Sunseed Nigeria Ltd, Mushin, Lagos), PKO (Ferdinand Oil Mills plc, Urualla, Imo State, Nigeria) and PO (Lever Brothers Nigeria plc, Agbara, Ogun State).

Preparation of degumming reagents

Anhydrous sodium carbonate (99.5%) was obtained from May and Baker Ltd, Dagenham, UK. Orthophosphoric acid GPR (85%, density 1.7g ml^{-1}) and sodium hydroxide pellets (96%) were from British Drug Houses (BDH) Chemicals Ltd, Poole, UK.

Degumming agents 0.5, 1, 2 and 5% (m/v) solutions (1 litre) each of NaOH, Na_2CO_3 and H_3PO_4 were prepared using distilled water.

Procedures for degumming treatment

Aliquots of 12 ml of each prepared chemical reagent were used in degumming 150 ml of each crude oil (GNO, PKO and PO) at 65°C, as described by Norris (1980). Another set of samples from the crude oils was subjected to other refining processes without prior degumming. The results are reported below as 'untreated'.

Alkaline and physical refining processes

In order to conduct a logical comparison between the test samples and the references (i.e. commercially refined oil samples), the test samples were subsequently subjected to other refining processes after degumming them: Each sample (100 ml) from the degummed or 'untreated' batches was neutralized at 60°C using 15 ml of 2.5 N NaOH solution (alkaline refining) and washed according to the BSI (1975) method.

For the filtering medium, a clay sample collected from the Awgu Ndeaboh Shale Group formation (latitude 6°5′, longitude 7°28′) in Nigeria as identified by Oboh *et al.* (1987) was activated (20 ml of acid solution in 50 g of 425-micron dry clay) with a 35% (m/v) solution of sulphuric acid, GPR, (98%, density 1.835 g $litre^{-1}$; BDH Chemicals Ltd, Poole, UK) according to the method of Mansfield (1936). The neutralized sample (100 ml) was filtered with 15 g of activated clay thrice (Whatman No. 4) and packaged for further analyses.

Chemical and physical analyses

These were determined on a total of 45 samples: degummed (36), undegummed: 'untreated' (3), reference (3), and crude oil (3) samples.

Percent yield-after-filtration was determined by filtering a 100 ml sample of degummed/'untreated' oil through a 15-g activated clay filter bed thrice at 50°C. Dynamic viscosity (30 ± 2°C) was determined using a spindle No. 1 of the Synchrolectric Viscometer Model LVF (Brookfield Engineering Laboratories Inc., Stoughton, MA, USA) at a constant rotational velocity of 60 rev/min. The red (R) and yellow (Y) colour readings were measured with a Lovibond tintometer (5.25 in. cell) according to the AOCS (1977) method. The total colour was estimated from (5R + Y) for GNO and PKO, (Philip & Abraham, 1979) and (10R + Y) for PO (Oboh & Aworh, 1987). Colour reduction (%) was estimated by calculation (Hymore & Iyayi, 1987). Smoke points (Mondy, 1980), free acid (AOAC, 1984) and peroxide values (BSI, 1975) were also determined.

Statistical analyses

Data obtained from the chemical and physical analyses as functions of oil type (3), degummer type (3) and degummer strength (5) were statistically assessed using the three-way analysis of variance (ANOVA) technique, as described by Steel & Torrie (1980) to determine how significant the differences are according to the main effects and their interactions.

RESULTS AND DISCUSSION

Results of the effects of degummer type and strength of degumming reagent on the chemical and physical characteristics of edible vegetable oils are shown in Table 1 (palm oil, PO), Table 2 (palm kernel oil, PKO) and Table 3 (groundnut oil, GNO).

Free fatty acids (FFA) were highest in the crude PO (5.63%, Table 1) and lowest in GNO (1.13%, Table 3). The results from degumming treatments during refining showed that reductions in FFA (%) are in the ranges of 79.1–99.9 for PO, 89.3–99.9 for PKO, and 65.0–99.7 for GNO, with the highest effect being achieved with 5% NaOH solution and the lowest with 5% H_3PO_4. It was also observed that H_3PO_4, as a degumming reagent, has a tendency to increase the FFA, especially if the acid is not properly neutralized or washed out of the oil. As such, during FFA determination, titration is not only against the FFA but also against the residual H_3PO_4, thus resulting in high figures for FFA (Tables 1–3). Statistically, the observed slight differences were significant ($P = 0.05$) with respect to the major factors (D), (OT) and (DS) and two of their first order interactions (OT) (DS) and (D) (DS) (Table 4). This implies that variations in the mentioned factors will greatly influence the index of degree of (hydrolytic) rancidity (FFA).

Results for the peroxide value (PV) show that GNO has the least reduction in PV due to the refining (degumming treatments) process. The PKO is judged to be the most oxidatively stable oil among the three test samples, since PV is used to assess the extent of oxidative rancidity (Henick, 1978; Weiss, 1983). This confirms the on-the-spot assessment of the test samples by industrial workers in which the off-flavour defect was not detected. The highest overall effect was by NaOH while the least was by H_3PO_4 (Tables 1–3). Statistically, there were significant differences in PV at the 5% level of confidence due to five out of the six sources of variation (Table 4). This outcome underscores the critical position of PV as an important quality criterion.

Table 1. Data for chemical and physical characteristics of refined palm oil (PO) as affected by varying strengths of degumming reagents

Characteristic	Degummer type, and strength of degummer (%)												Untreated[a]	Reference[b]	Crude
	NaOH				Na_2CO_3				H_3PO_4						
	0.5	1	2	5	0.5	1	2	5	0.5	1	2	5			
Free fatty acid (%)	0.030	0.020	0.011	0.006	0.036	0.026	0.015	0.007	0.040	0.031	0.020	0.011	1.18	0.015	5.632
Peroxide value (meq/kg)	0.002	0	0	0	0.12	0.08	0	0	0.12	0.10	0.10	0.06	0.44	0.02	0.60
Yield-after-filtration %	78.0	80.0	83.0	85.0	72.0	74.0	76.0	77.0	76.0	78.0	80.0	82.0	73.0	—	—
Total (Lovibond) colour[c]	47.0	46.0	45.0	43.0	84.0	80.0	76.0	54.0	119.3	110.0	98.0	88.0	115.0	89.0	320.0
Colour reduction (%)	85.31	85.63	85.94	86.56	73.75	75.00	76.25	83.13	62.72	65.63	69.38	72.50	64.06	—	—
Dynamic viscosity (mPa s)	24.6	32.1	20.5	20.0	25.3	24.2	22.5	21.2	24.3	22.3	20.2	19.5	34.2	22.0	104.0
Smoke point (°C)	218.0	225.0	232.0	236.0	210.0	220.0	229.0	234.0	208.0	218.0	227.0	234.0	184.0	229.0	115.0

[a]Sample that was not degummed.[b]Commercially refined PO.[c]Total colour calculated from (10R + Y), R = red, Y = yellow colour readings.

Table 2. Chemical and physical characteristics of refined palm kernel oil (PKO) as affected by varying strengths of degumming reagents

Characteristic	Degummer type, and strength of degummer (%)												Untreated[a]	Reference[b]	Crude
	NaOH				Na_2CO_3				H_3PO_4						
	0.5	1	2	5	0.5	1	2	5	0.5	1	2	5			
Free fatty acid (%)	0.028	0.020	0.013	0.005	0.032	0.024	0.016	0.006	0.040	0.028	0.013	0.008	0.48	0.017	4.48
Peroxide value (meq/kg)	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0	0.3
Yield-after-filtration (%)	75.0	77.0	80.0	82.5	60.0	60.0	73.0	80.0	72.0	73.0	74.0	76.0	72.0	—	—
Total (Lovibond) colour[c]	36.8	34.0	33.2	29.02	31.5	30.0	27.5	26.0	30.5	29.5	27.0	25.5	41.4	23.5	72.0
Colour reduction (%)	48.9	52.8	54.2	59.72	56.3	58.3	61.8	63.9	57.6	59.0	62.5	64.6	42.5	—	—
Dynamic viscosity (mPa s)	16.5	15.5	15.2	14.6	18.3	16.4	15.2	15.0	18.0	16.2	15.0	14.8	22.4	15.3	32.0
Smoke point (°C)	215	229	236	245	213	225	234	244	210	219	235	243	196	232	143

[a]Sample that was not degummed.[b]Commercially refined PKO.[c]Total colour calculated from (5R + Y), R = red, Y = yellow colour readings.

Table 3. Chemical and physical characteristics of refined groundnut oil (GNO) as affected by varying strengths of degumming reagents

Characteristics	Degummer type, and strength of degummer (%)												Untreated[a]	Reference[b]	Crude
	NaOH				Na_2CO_3				H_3PO_4						
	0.5	1	2	5	0.5	1	2	5	0.5	1	2	5			
Free fatty acid (%)	0.018	0.012	0.007	0.003	0.024	0.011	0.008	0.005	0.039	0.029	0.017	0.006	0.395	0.011	1.13
Peroxide value (meq/kg)	0.5	0.3	0.2	0.1	1.0	0.6	0.4	0.2	1.0	1.0	0.6	0.6	1.8	0.20	5.6
Yield-after-filtration (%)	83.0	85.0	86.0	88.0	64.0	76.0	76.0	84.0	82.0	85.0	86.0	86.0	75.0	—	—
Total (Lovibond) colour[c]	18.5	16.0	15.0	14.0	31.0	24.0	19.0	16.5	22.5	20.5	18.0	16.0	23.0	21.5	54.0
Colour reduction (%)	65.7	70.4	72.2	74	42.6	55.6	64.8	69.4	58.3	62.0	66.7	760.4	57.41	—	—
Dynamic viscosity (mPa s)	18.0	17.3	17.0	16.9	18.0	17.5	17.1	17.0	18.2	17.2	17.0	17.0	20.4	17.0	34.5
Smoke point (°C)	230	238	244	250	226	240	244	248	212	219	235	246	199	240	179

[a] Sample that was not degummed. [b] Commercially refined GNO. [c] Total colour calculated for (5R + Y), R = red, Y = yellow colour readings.

Table 4. Analysis of variance for some quality characteristics of degummed edible vegetable oils

Source of variation		Reduction in sum of square (SS) for the characteristics					
	Degree of freedom	Free fatty acid (%)	Peroxide value (meq/kg)	Yield-after filteration (%)	Colour reduction (%)	Dynamic viscosity (mPa s)	Smoke point (°C)
Oil type, OT	2	0.23331*	5.26*	391.64*	2773.97*	509.93*	1153 *
Degummer, D	2	0.00041*	0.2018*	426.84*	192.50*	3.03*	292.13*
Degummer strength, DS	2	3.202*	2.66*	524.98*	1536.92*	411 *	13273.91*
OT × D	4	0.000067^{NS}	0.2525*	35.69^{NS}	688.19*	3.08*	111.467
OT × DS	8	0.8806*	2.05*	81.02^{NS}	188.29^{NS}	107 *	127.689*
D × DS	8	0.00022*	0.0866^{NS}	210.49*	105.88^{NS}	1.19^{NS}	183.422*
Error	16	0.000091	0.1138	110.311	270.536	2.19	86.98

At 5%, F value (2,16) = 3.63, (4,16) = 3.01 (8,16) = 2.59.*Significant at 5% level of confidence.^{NS}Not significant.

The Lovibond colour values of the oil samples show that NaOH degumming gave the greatest % colour reduction (CR) while H_3PO_4 gave the least in PO and GNO. However, the reverse trend occurred in PKO. The PKO showed the lowest overall colour reduction.

This is a measure of the magnitude and degrees of reduction of the principles that contribute to colour of oils. The differences in CR, due to oil type (OT), degummer (D), degummer strength (DS) and (OT) (D) interaction, are significant at 5% levels.

The data for dynamic viscosity (DV) showed that crude PO exhibited the highest resistance to flow with a DV of 104 mPa s, while crude PKO showed the least with a DV of 42 mPa s. Crude GNO has a DV of 34.5 at 30 ± 2°C while Cobb & Johnson (1973) reported a viscosity range of 71.1–86.2 mPa s at 20°C for GNO. The variation is expected since the DVs of liquids relate directly to temperature (Rao, 1986). However, after the degumming treatments (refining), the DVs were considerably reduced (Tables 1–3). The % reductions are in the ranges of 67.1–81.3 (PO), 30.0–54.4 (PKO) and 40.9–87 (GNO). The lower range figures are for the undegummed-refined samples. The highest fluidity (inverse of viscosity) due to degumming was found in PO, caused by H_3PO_4, while the highest in GNO and PKO were effected by NaOH. The results implied that the waxes and other degrading impurities, that enhance the DV of oil, must have been removed during the course of degumming treatments, as the DVs of the undegummed oil samples were still much higher than the degummed ones (Tables 1–3). The DVs of treated oil samples compared very favourably with those in the literature.

This observation is suggestive that viscous-causing glycero-phosphatides (Chikoti, 1988) have been largely removed (81%). Analysis of variance (ANOVA) results in Table 4 show that the differences in DV due to five sources of variations are significant at the 5% level of confidence. This means that the isolated and interacting/simultaneous influences due to degummer (D), degummer strength (DS) and oil type (OT) play an important role in affecting the degree of flowability of edible vegetable oils.

Data obtained for % yield-after-filtration (YAF) (Tables 1–3) show that YAF varied with the oil type (OT), (D) and (DS). The highest YAF was from GNO (88%), effected by the 5% NaOH degumming reagent, while the lowest was from the 0.5% Na_2CO_3-degummed PKO (64%). This indicates that the DS is directly proportional to the YAF and inversely to DV, underscoring the need for a well-co-ordinated degumming stage in the oil refining process.

The results for smoke points (SP) (Tables 1–3) show that figures for the crude oils are 115°C (PO), 143°C (PKO) and 179°C (GNO). The degumming treatment yielded SP ranges of 210–245°C (PKO), 208–236°C (PO) and 212–250°C (GNO). This result is indicative of substantial elimination of substances (proteinaceous matter; Weiss, 1983) that reduce smoke points. These figures compare very well with those in the literature. The highest SP which is from GNO was due to 5% NaOH solution, while the lowest (from PO) was due to the 0.5% H_3PO_4 reagent. Weiss (1983) has reported that a good frying shortening (lipid) should have a minimum SP of 218°C. Since SP is a measure of thermal stability of oil during shallow and deep fat frying, this means that most oil samples obtained from this experiment are thermostable. The results further show that the degumming exercise effected a very sharp increase in the SP of PO (105%, by NaOH) while the lowest increase is in GNO (37.4%, by H_3PO_4). The ANOVA data (Table 4) show that all the sources of variation are statistically significant at the 5% level. This means that SP is the most vital index/criterion for assessing the cooking quality of edible oil.

CONCLUSIONS

The degummed local, edible vegetable oils compared well with the commercially available brands (references) in their physical and chemical quality parameters. The type and strength of degummer, as well as type of oil, affected these measured characteristics. There was a general improvement in the quality of the oils due to the degumming treatment. This study has demonstrated that the characteristics of vegetable oils can be controlled by manipulating the type and strength of the degumming reagent during the process of refining. An overall grading of the test parameters in order of importance is thus: Smoke point > DV > PV > FFA > CR > YAF.

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REFERENCES

Al-Kahtani, H. A. M, Hanna, M. A. & Handel, A. P. (1984). Effect of water quality on degumming and stability of soyabean oil. *JAOCS*, **61**(1), 94–7.

AOAC (1984). *Official Methods of Analysis* (14th edn), ed. S. Williams. Association of Official Analytical Chemists, Arlingon, VA, USA.

AOCS (1977). *Official and Tentative Methods of Analysis* (3rd edn), ed. W. E. Link. American Oil Chemists' Society, Champaign, Ill., USA.

Asiedu, J. J. (1989). Refining of vegetable oils. In *Processing Tropical Crops—A Technological Approach*. MacMillan Press Ltd, London, UK, pp. 186–97.

Banigo, E. O. I., Ogunlesi, A. & Ofi, O. (1977). Manufacture of palm kernel oil using the traditional coconut oil processing system. *JAOCS*, **54**(12), 593–4.

BSI (1975). *Methods of Analysis of Oils*: BS 684. British Standards Institute, London, UK.

Carr, R. A. (1976). Degumming and refining practices in the U.S.A. *JAOCS*, **53**, 332–3.

Chikoti, G. (1988). Commercial production of cooking oil at Premium Oil Industries, Lusaka, Zambia. In *Proc. Zambia Workshop on Oilseed Expression*, Kafue, Zambia, 27–30 October 1987, pp. 50–4.

Cobb, W. Y. & Johnson, B. R. (1973). Physical–chemical properties of peanuts. In *Peanuts: Culture and Uses*. Stone Printing Co., Roanoke, VA, USA.

Cornelius, J. A. (1983). Palm kernel oil processing. In *Processing of Oil Palm Fruit and its Product*. Tropical Products Institute, London, UK, pp. 46–9.

Haraldsson, G. (1983). Degumming, dewaxing and refining. *JAOCS*, **60**(2), 251–6.

Henick, A. S. (1978). Rancidity. In *Encyclopedia of Food Science*, eds M. S. Peterson and A. H. Johnson. Avi Publ. Co. Inc., Westport, Conn., USA, pp. 658–9.

Hymore, F. K. & Iyayi. A. F. (1987). Performance of some local clay samples in the bleaching of palm oil. In *Proc. Conf. Engineering and Technological Development*. University of Benin, Benin, Nigeria, pp. 107–13.

Ihekoronye, A. I. and Ngoddy, P. O. (1985). Application of fats and oils in the food industry. In *Integrated Food Science and Technology for the Tropics*. Macmillan Publ. Ltd, London, pp. 77–85.

Jung, M. Y., Yoon. S. H. & Min, D. B. (1989). Effects of processing steps on the contents of minor compounds and oxidation of soybean oil. *JAOCS*, **66**(1), 118–20.

List, G. R. Avellaneda, J. M. & Mounts, T. L. (1981). Effect of degumming conditions on removal and quality of soyabean lecithin. *JAOCS*, **58**(10), 892–1101.

Mansfield, G. R. (1936). Clay investigation in the Southern States, 1934–1935. *U.S. Geol. Surv. Bull.*, **901**, 1–22.

Mondy, N. I. (1980). *Experimental Food Chemistry*. Avi Publ. Co. Inc., Westport, Conn., p. 147.

Mwale, J. M. (1987). Quality and storage stability of rurally produced oils. In *Proc. Zambia Workshop on Oilseed.* Expression, Kafue, Zambia, pp. 85–9.

Nash, A. M., Frankel, E. N. & Kwolek, W. F. (1984). Degumming soyabean oil from fresh and damaged beans with surface-active compounds. *JAOCS*, **61**(5), 921–3.

Norris, F. A. (1980). *Balley's Industrial Book of Oils and Fats*. Interscience Publishers Inc., New York, USA, pp. 264–8.

Oboh, A. O. & Aworh, O. C. (1987). The use of Nigerian clays in vegetable oil refining. II. Quality of palm oil bleached with acid-activated Nigerian clays. *Nigerian Food J.*, **5**, 52–6.

Oboh, A. O., Aworh, O. C. & Akagu, O. K. (1987). The use of Nigerian clays in vegetable oil refining. I. Evaluation of some Nigerian clays as potential bleaching earths. *Nigerian Food J.*, **5**, 45–51.

Philip, S. & Abraham, A. (1979). Changes in the of coconut oil due to storage of copra. *Indian Phytopathology*, **32**(3), 453–5.

Racicot, L. D. & Handel, A. P. (1983). Degumming of soyabean oil: quantitative analysis of phospholipids in crude and degummed oil. *JAOCS*, **60**(6), 1098–101.

Rao, M. A. (1986). Rheological properties of fluid foods. In *Engineering Properties of Foods*, eds M. A. Rao & S. S. H. Rizvi. Marcel Dekker Inc., New York, pp. 1–47.

Rushing, J. E. (1983). Soyabean oil phospholipids: occurrence of protein with phospholipids in degummed soyabean oil. *Diss. Abstr. Int.*, B **43**(11), 3524.

Sharma, N. K., Taneja, V. K., Wagle, R. D. and Patel, S. M (1985). Processing of prepressed solvent-extracted oil from Indian soyabean: refining loss studies. *JAOCS*, **62**(4), 725–7.

Smiles, A., Kakud, Y. & MacDonald, B. E. (1988). Effect of degumming reagents on the recovery and nature of lecithins from crude carona, soybean and sunflower oils. *JAOCS*, **65**(7), 1151–5.

Steel, R. G. D. & Torrie, J. H. (1980). Analysis of variance III: factorial experiments. In *Principles and Procedures of Statistics—A Biometrical Approach*, 2nd edn. McGraw-Hill, London, UK, pp. 336–76.

Weidermann, L. H. (1981). Degumming of fats and oils. *JAOCS*, **53**, 408–9.

Weiss, T. J. (1983). Physical and chemical properties of fats and oils. In *Food Oils and Their Uses* (2nd edn). Avi Publ. Co. Inc., Westport, Conn., USA, pp. 25–31, 44–84.