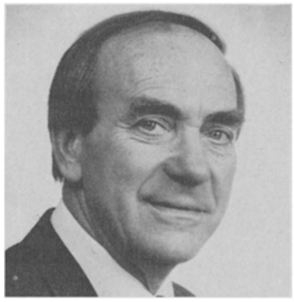
Oilseed Quality Requirements for Processing



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ABSTRACT

Current oilseed trade and trading specifications for soybeans, rapeseed, sunflower seed, palm kernels and copra are reviewed and compared with crude oil quality specifications, palm oil included. The limitations of the quality indices of the oilseeds are discussed with reference to present day needs of refiners producing end products of good quality, stability and yield. The developing, more stringent demands of physical refining on crude oil quality are outlined. The influence of seed quality, handling and the capability of the crusher to influence quality and yield with current technology is assessed. Particular reference is made to the degree of extraction, phosphatides, chlorophyll, waxes, free fatty acids and bleachability. Desirable attributes in specifications are listed and recommendations made which could benefit both processor and grower in the long term and facilitate international trade.

INTRODUCTION

The seed is the beginning, and in the case of oilseeds, the beginning is the start of a process which affects the life of each individual to some extent. The vegetable oils and fats when separated from the seeds are essential to the nutrition of the world's population, contributing energy and essential fatty acids to the diet. Vegetable proteins in the residual oilcakes and meal are converted to animal protein when used in animal feedstuffs and contribute essential nutrients and variety to the human diet. The economy of many countries, whether developing or in an advanced stage of development, depends to some extent on cultivation, processing or export of vegetable oilseeds. As an example, in the United Kingdom in recent years, industries using products supplied by the seed crushing and oil processing industry accounted for some 22% of total employment in manufacturing.

If the oilseed is the beginning, where is the end? And what are the quality criteria necessary to achieve this end? For the purpose of this paper, we are concerned with oilseed requirements for processing which will enable the crusher to produce crude oils in good yield. The quality of these oils must satisfy the changing needs of the refiner who now is increasingly using physical refining to replace or supplement traditional refining processes. The refiner's requirements for caustic processing of soybean oil have been discussed by Young (1) who stresses that, despite improvements in technology, a good quality edible oil cannot be obtained from a poor crude oil. This statement has even greater significance when processing by physical means.

TRADE IN OILSEEDS

At the 1981 World Congress of the International Association of Seed Crushers (IASC) the President (2) pointed out that "developing and Eastern countries are now as significant importers as Western Europe if seed and oil imports are combined, e.g., Nigeria and Russia have become importers, and the long-term shift in world oil trade has been the increasing dominance of developed countries as exporters (e.g., Malaysia, Brazil and Argentina)". Soybean, sunflower, rapeseed, palm and lauric oils (coconut and palm kernel) are the most important vegetable oils in terms of volume produced and in exports. From the crusher's standpoint, however, it is the oilseed exports which are of prime interest. Trends calculated from recent statistics (3) for these products are shown in Figure 1. It can be seen that against an overall background of rising world exports of seed and oil (in oil terms) there is an overall decline in the percentage of seed exported in the last 4 years. The exception is sunflower seed, which showed some recovery in 1981. The most marked change is the decline in exports of copra and palm kernels.

These features have entailed changes in the crush pattern, particularly in Western Europe, with the tropical oilseeds decreasing and soybeans, sunflower and rapeseed dominant. Here again the soybean crush has fallen recently as political strings have manipulated prices in Brazil to encourage local crushing and export of cheap soybean meal (4). Similar action has encouraged the processing of palm oil in Malaysia and the export of refined products so that 90% of their increasing exports are now refined. European refiners have reduced palm oil usage by 22% since 1977.

This changing pattern of trade requires increasing vigilance and attention to detail in contracts to ensure the maintenance of quality standards.

TRADE SPECIFICATIONS FOR OILSEEDS AND CRUDE OILS

In international trade, about 80% of all oilseeds, oils and fats are handled on FOSFA (Federation of Oils, Seeds and Fats Associations) contracts (5). Quality attributes and

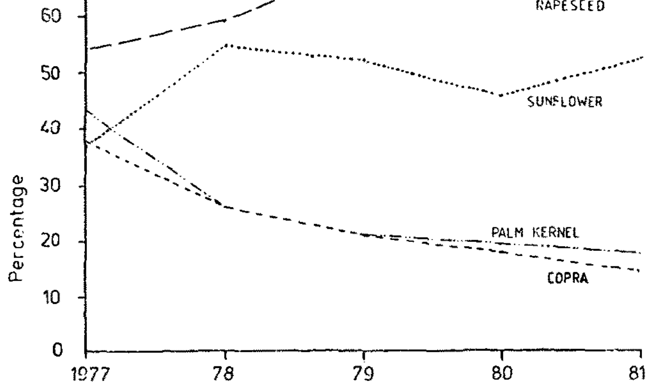

FIG. 1. Percentage of world exports of individual oilseeds exported as seeds, e.g., exports as seed of each oilseed (calculated as oil) = a; exports of oil derived from each oilseed = b; percentage = [a/(a+b)] X 100.

methods of analysis are defined and the expertise of FOSFA approved analysts monitored by a Quality and Laboratory Committee. Details of FOSFA contracts, analytical methods, etc., are recorded in their recently published manual (6). Other major trade Associations are the National Soybean Processors Association (NSPA) whose members process and market more than 95% of all soybeans crushed in the USA and issue rules and specifications (7) for trade in soybean oil and meal products. The NIOP (National Institute of Oilseed Products) issues Trading Rules and the American Fats and Oils Association issue contracts including an export contract for vegetable oils. The Netherlands Oils Fats and Oilseeds Trade Association (NOFOTA) issues a number of contracts, and a number of official institutions and associations are concerned with methods for grading, sampling, sample preparation and analysis. A comprehensive list with addresses is given in a recent publication by the International Association of Seed Crushers (8).

Soybeans and Soybean Oil

The quality clauses in the main export contracts for soybeans are shown in Table I and the USDA standards of the Federal Grain Inspection Service (FGIS) (9) in Table II. The Canadian standards were established under the Canada Grain Act and are interpreted in the Grain Grading Guide by the Canadian Grain Commission (10). There are 5 classes based on color, i.e., yellow, green, brown, black and mixed soybeans, and each class is divided into 4 numerical grades and sample grade. The grading criteria used are similar but not necessarily equivalent, e.g., Canada No. 2 contains up to 15% splits and should be practically free from heat-damaged kernels. Both systems of grading are very comprehensive, relying on subjective assessments and physical methodology rather than chemical factors. The basic philosophy is that any departure from sound whole seed in the form of damage, color, contamination, etc., contributes to a downgrading. It assumes that this classification parallels oil content, oil quality, protein content and protein quality, all of major economic significance to the processor particularly with a low oil content seed. The grade classifications of both countries are accepted as final for export purposes.

The NSPA specification for crude degummed soybean oil (7) is used for most export contracts. It includes free fatty acid (FFA/oleic) 0.75% (1.25% maximum with allowances); moisture and impurities 0.3%, phosphorus 0.02% (0.025% maximum); unsaponifiable matter 1.5%, and flash point (F) 250 min. The quality requirement is that the oil shall be pure and produced from fair average quality (FAQ) crude soybean oil from which a major portion of the gums have been removed by hydration and separation and, moreover, equal in quality to soybean oil produced for domestic consumption.

This is of interest and could be interpreted to mean that a color and refining loss are implicit in the specification, as oil for domestic use in the USA includes these items in the specifications. Norris (11) in a recent paper provides further detail on NSPA quality standards including the fully refined oil, and Thomas (12) has discussed other proposed specifications for crude degummed soybean oil. The most detailed list of oil specifications including fully refined oils is recorded by Brekke (13). It is reasonable to assume that the crushers' minimum oil target quality would be the NSPA spcification and, as the United States is the major exporter of soybeans, the FGIS grade is final for shipping quality. As regards yield, only FOSFA 22 and NOFOTA contracts give a direct guide since the basis is oil content analysis on arrival.

A timely reminder that oilseeds are natural products subject to the vagaries of climate is given by List (14). The effect of frost damage on oil content, color and refining loss of the oil is emphasized, as well as field and storage damage due to poor harvesting causing similar problems. The theory is that damage causes downgrading of hydratable to nonhydratable phosphatides contributing to high refining losses by emulsion formation in the caustic refining process. Other factors are the raised level of FFA when beans are stored above 13.0% moisture levels when storage fungi produce hydrolytic lipases, and prolonged exposure to wet weather in the field which activates lipase in the seed, pro-

TABLE I

Contractual Quality: Soybeans

Contract	NOFOTA 24	FOSFA 22	FOSFA 23	FOSFA 24	FOSFA 24A
Source	Ex ship	Argentine Brazil Paraguay yellow	Nigeria	USA Canada	Open
Quality	Sound FAQ of shipment month	FAQ[a] of shipment month	FAQ[b]	USDA FGIS[d] Grade final CGC Grade[e] final	GMQ
Oil tq (%)	√[c]	18.5[c]	–	–	√[c]
Admixture (%)	–	1.0[b] 2.0 max	1.0	– USA	1.0[b] 2.0 max
Foreign matter (%)	√[c]	–	–	1.0-5.0	–
Moisture (%)	–	14.0 max[b]	–	13.0-18.0	14.0 max[b]
Castor and poisonous seeds	–	Free	–		Free

[a]Fair average quality.
[b]Shipment basis.
[c]Arrival basis.
[d]USDA Federal Grain Inspection Service.
[e]Canadian Grain Commission.
√ = Included by agreement; tq = tale quale; GMQ = good merchantable quality.

ducing a similar degradation. These observations support the current grading scheme where frost and weather damage are rightfully included in a comprehensive list of different types of damage including heat damage. There is a warning, however, that damage to minor constituents may not be visible. Raised iron levels, for example, in the beans, further accentuated in the crushing plant, can give rise to oils outside the normal range of 1-3 ppm Fe which require special processing treatment. The raised iron content correlates well with FFA increase. A further note of caution is added inasmuch as the AOCS bleachability test, using 4% earth can given an optimistic appraisal of quality to the refiner using 0.5% earth under normal circumstances.

The American Soybean Association (ASA) is committed to reviewing current grading standards by a resolution passed at the 1978/79 convention (15) with a view to including protein and oil content in the standards. Discussing these factors, Frahm (16) points out that nearly all soybeans produced are separated into oil and protein fractions and under certain market conditions, e.g., soybeans at $5.80/bushel, a 1% variation in oil content equates to 15 cents/bushel and a 1% variation in protein content to 11 cents/bushel. In 1977, an interstate survey gave a range of 1.9% oil and 3.5% protein, whereas an earlier study in North Carolina showed a range of 3.9% oil and 5.0% protein. There is evidently sufficient variation to consider the inclusion of at least one of these factors in standards. There is also controversy over moisture levels (17), but at a recent meeting (December 1981) of the FGIS Grain Quality Standards Committee in the presence of ASA members, it was evident from reports (I.R. Leysen, private communication, 1982) that there had not been a great lobby in this direction. Leysen (18) had indicated earlier (1979) that US growers and industry groups generally do not support a change in current standards.

Rapeseed and Rapeseed Oil

The main exporting country for rapeseed is Canada and, as with soybeans, grading standards were established under the Canada Grain Act and are controlled by the Canadian Grain Commission (10). There are 3 grades primarily based on subjective and physical assessment as detailed in Table III.

The seed must be sound and of good natural color judged against a standard sample. Damaged seeds are classed as shrunken, shrivelled or discolored by mold or frost and seeds with green endosperms. Vivid green and heat discolored seeds are counted after crushing on an indented seed counter. The relevance and importance of this assessment to oil quality is demonstrated by the data in Table IV on Swedish seed.

The importance of chlorophyll levels in the seed has been recognized in Sweden, where payments to farmers take account of chlorophyll content in the oil. Immature seed with high chlorophyll levels (19) can lead to a bluish green color in the oil which is difficult to remove on refining. The maximum Lovibond color (1" cell) for normal Swedish crude oils is 3 red, 125 yellow, 2 blue. This corresponds with a level of chlorophyll in oil of 30 ppm, which is now set as the maximum for first-grade seed. Above this

TABLE II

US Soybean Grading Requirements: Maximum Tolerances (%) (9)

Grade	Minimum test weight per bushel (lb)	Moisture	Splits	Damaged kernels: Total	Damaged kernels: Heat damaged	Foreign material	Brown black and/or bicolored soybeans in yellow or green soybean
1	56	13.0	10	2.0	0.2	1.0	1.0
2	54	14.0	20	3.0	0.5	2.0	2.0
3	52	16.0	30	5.0	1.0	3.0	5.0
4	49	18.0	40	8.0	3.0	5.0	10.0

Sample grade: Below Grade 4. Contains 50% min whole or broken soybeans and 10% max other grains, e.g., wheat, corn, flax, etc.
Purple mottled or stained beans rate Grade 3 max.
Materially weathered beans rate Grade 4 max.

TABLE III

Canadian Rapeseed Grading Requirements: Maximum Tolerances (%) (Canada Grain Act and reference 10)

Grade	Damage: Heated	Damage: Distinctly green	Damage: Total damage[a]	Admixtures of foreign material: Stones	Admixtures of foreign material: Total conspicuous	Admixtures of foreign material: Total inconspicuous[b]	Moisture
No. 1 Canada	0.1	2	3	0.05	1	5	10.0
No. 2 Canada	0.5	6	10	0.05	1	5	10.0
No. 3 Canada	2.0	20	20	0.05	1	5	10.0

[a]Damage includes distinctly shrunken or shriveled seeds as from frost, discolored as from mold, completely rimed or excessively weathered, sprouted, distinctly green, or heated. Broken seeds not assessed as dockage are considered sound.

[b]Includes common wild mustard and/or domestic brown or oriental mustard seed. For each grade, commercially clean seed contains 2.5% dockage which includes 1% conspicuous foreign material.

TABLE IV

Relation between Rapeseed Quality and Oil Quality

	Chlorophyll (ppm)	FFA/oleic (%)
High-quality pure rapeseed	12	0.5
Damaged seed	50	5.0
Germinated seed	100	8.0
Weed seeds	900	10.0

level, extra refining is necessary to produce an oil of satisfactory taste and stability. The relation between damaged seed and green color of the oil in the Canadian grading system was recorded (20) in 1970. Daun (21) has contributed some interesting work in a recent paper which demonstrates a poor correlation between the "percentage green seed" count and the chlorophyll level in the seed or oil. From a large number of samples taken in crop surveys in 1979 and 1980, as well as samples from farms and crushing plants, only about half the changes in chlorophyll content could be predicted by changes in green seed levels. Daun also highlights the problems that Canadian crushing plants have in achieving the Canadian Government Specifications Board (CGSB) standard (22) for crude and degummed rapeseed oil colors. Laboratory extracted oils could readily be matched with the green nickel sulphate standard, whereas plant produced oils could not. He postulates that the difficulty is caused by conversion of green colored chlorophyll to russet-colored pheophytin in the crushing process. This change entails reduced absorptivity and a shift to higher wavelengths in the absorption spectra. The CGSB color standard can be matched with a level of 25 ppm chlorophyll in the oil which, it is suggested, is equivalent to a level of 20 ppm pheophytin. There are two important recommendations in this paper, namely: (a) the CGSB standard A should be replaced by an upper limit of 20 ppm pheophytin (measured by AOCS Official Method Cc 13d-55) with no change in factor; and (b) a maximum limit of 12 ppm chlorophyll in the seed should be adopted for No. 1 Canada rapeseed. The latter is approximately equivalent to the Swedish standard when calculated on a seed basis and would entail a reduction in the level of "distinctly green seed" allowable or its eventual replacement with a less subjective technique. Immaturity or greenness is the major degrading factor in Canadian rapeseed and the full impact of the problem can be measured by the fact that 30% of the samples collected throughout Western Canada had 1% or less green seed and greater than 12 ppm chlorophyll, whereas currently about 90% of rapeseed inspected annually is classed as No. 1 grade.

There is also concern at the level of dockage included in the seed grades. Dockage is material which can be removed from the seed by designated screening and aspiration equipment and is allowable in commercially clean seed parcels at levels of 2.5%. In a series of well designed experiments, Ismail et al. (23) produced crude dockage oil by prepress extraction and added levels of 0-4% to crude double zero rapeseed oil (canola oil). The stability of the refined, deodorized oil was markedly affected to the extent that the limitation of dockage to 1% was recommended.

Swedish and European rapeseed specification (24) are set out in Table V. In Sweden, oil from Grade 1 seed is used in margarine manufacture, Grade 2 oil is hydrogenated before use, and Grade 3 is not used for edible outlets. The whole emphasis in the grades is on oil quality with safeguards for the processor on FFA, chlorophyll, and lower moisture levels. UK rapeseed is traded internally on a similar basis to the European contract. It is doubtful whether much of the crop would meet the Swedish Grade 1 standard, as most of the crop yields oil over 1% FFA and chlorophyll levels are variable and high judged by crude oil colors. The contractual seed quality is shown in Table VI. It can be seen that, although the CGC grade is final on shipment, it does make significant strides in the interpretation of damaged seed. This factor is not included in admixture but is covered by the GMQ clause in FOSFA contracts. Typical oil specifications are listed in Table VII and the quality indices listed under "United Kingdom" in the Table are the main criteria used by FOSFA and the NIOP (Rule 159) for trade. The Canadian specification is used for internal trade, the interesting points being the low FFA and the inclusion of neutral oil by the chromatographic loss method. These factors bring the oil closer to internal US trading specifications for soybean oil and narrow down the differences

TABLE VI

Contractual Quality Rapeseed: Maximum Tolerances (%)

Contract	FOSFA[a,b] 26A	FOSFA[a,c] 26	FOSFA 35,36
Source	UK	Europe	Canada
Quality	GMQ	GMQ	CGC grade[d]
Oil tq	40.0	42.0	By agreement
Moisture	9.0	9.0	–
Admixture	2.0	2.0	–
Erucic acid	5.0	5.0	–

[a]Arrival basis.
[b]Optional rejection levels moisture and admixture.
[c]Rejection level 10% moisture, 4% admixture.
[d]CGC shipment grade and analysis final.

TABLE V

Swedish and European Rapeseed Grading Requirements: Maximum Tolerances (%)

	Sweden Grade 1	Sweden Grade 2	Sweden Unacceptable	European FOSFA 26
Appearance/smell	Subjective assessment			GMQ
Admixture	6	10	> 10	2.0
Moisture	6-8.5	6	> 8.5	9.0
Oil	–	–	–	40.0
Chlorophyll in oil (ppm)	40	70	> 70	–
FFA/oleic in oil	1	3	> 3	–
Erucic acid	7	15	> 15	5.0

Chlorophyll levels above 30 ppm entail price reductions.
European reject levels 10.0% moisture, 4% admixture.

in yield between the two competing oils for the processor. The higher FFA levels in Europe are possibly due to the growing of winter varieties of seed in contrast to spring varieties in Canada. In 1981, a standard export sample of Canadian rapeseed was analyzed at 0.44% FFA in our laboratories. The performance of the Canadian grading scheme and crushing industry can be assessed from a paper by Teasdale (25). During a 9-month period starting in July 1977, over 95% of shipments of crude degummed oil into a major Canadian refinery were well within the specification listed in Table VII, with the exception of residual phosphorus. More recently in the UK with Canadian seed we have experienced serious green color problems in our plant.

Palm Oil

Palm kernels and palm kernel oil. An appreciation of the quality of palm oil, palm kernels and palm kernel oil involves a basic understanding of the palm fruit and the varietal development from the African Dura, the Sumatran Deli Dura, to the current thin-shelled Tenera variety of Malaysia. This has been adequately reviewed (26,27) and will also be covered elsewhere in this conference. It is a major achievement in maximizing the yield of palm oil from the mesocarp (pulp) of the palm fruit by cross-breeding, producing a thin-shelled smaller nut. The ratio of mesocarp to shell in the Malaysian tenera fruit is of the order of 75-80: 17 compared with the African dura 46-56: 35, whereas the Sumatran deli dura has an intermediate value. This change, together with the introduction of continuous screw presses to replace the hydraulic presses, (28) has produced a greater size variation in the nuts which, together with the thinner shells, has produced problems with broken kernels. The contractual quality of palm kernels is listed in Table VIII. In basic terms, the crushing yield is protected by inclusion of oil content and FOSFA 29 gives a limited protection on FFA. The bulk of the quality factors on the other hand are described as "good merchantable quality" and are arguable. The deleterious effect of moisture, broken and discolored kernels on oil quality has been highlighted over a period of years (29,30), contracts have remained unchanged and quality has deteriorated. For example, in 1965, samples of Nigerian kernels contained 6.3% broken seed. In 1982, the mean of 8 shipments from Nigeria was 9.4% with a wide range from 1.2% to 15.3%. With the present situation where more kernels are being crushed in the countries of origin, it is even more important to reexamine the quality attributes in the contracts and consider whether damaged kernels at least should be included as they are not currently included in admixture.

Trading quality standards for palm kernel oil are given in Table IX and, with the large increase in oil exports at the expense of seed, reduction in the FFA basis of 5% should be considered. In our experience, Malaysian oil shipments have ranged from 2.0% to 3.5% FFA. Admittedly, there are penalties for high FFA levels but these may not be sufficient to cater for iron pick-up, color deterioration as well as refining loss. It is also noted that a number of shipments of imported palm kernel oil have a yellow color and carotene levels above the norm of 4.4 ppm are quoted as typical (31). One can only assume this is due to absorption of palm oil by the thinner tenera shells or due to breakage and palm oil penetration of the kernels. Since it is of recent occurrence, the latter explanation appears to be the most feasible.

Palm oil is pressed from the mesocarp of the palm fruit and careful attention to harvesting and handling of the fruit bunches is essential to achieve a satisfactory yield and quality of oil. The techniques involved are now well known and consumer demand has resulted in special grades of palm oil with reduced FFA and oxidized oil content. This entails increased frequency of harvesting and reduced yield due to harvesting underripe fruit. As a consequence, the oil is sold at a premium over standard. Young (32) has discussed the

TABLE VIII

Contractual Quality: Palm Kernels

Contract	FOSFA 27	FOSFA 29	NIOP Rule 110
Source	Open	Open	Named
Quality	GMQ	GMQ	FAQ of season[b]
Oil tq (%)	49[a]	49[a]	49[a]
FFA/lauric (%)	–	4.75[a]	–
Shell and dirt (%)	–	2.75[a]	–

[a]Arrival basis.
[b]Shipment basis.

TABLE VII

Quality Specifications for Crude Rapeseed Oil

	Crude degummed					Crude
	Unilever			Canada		
	Sweden	Germany	Typical	1976	Proposed	UK
FFA/oleic (%)	1.3	1.5 max	2.4	1.0 max	0.5	2.0 max
Volatile matter (%)	0.15	0.25 max	–	0.3 max	0.3 max	0.5 max
Impurities (%)	0.02		–			
Erucic acid (%)	–	5.0 max	–	5.0 max	5.0 max	5.0 max
Chlorophyll (ppm)	20 max	30 max	24	–	–	–
Phosphorus (ppm)	200–	200 max	146	200	50	–
RB Color (red)	–	–	–	1.5 max	1.0 max	–
Peroxide value (me)	1.0 –	–	–	–	–	–
Anisidine value	2.0–2.5	–	–	–	–	–
Totox	6.0 max	–	–	–	–	–
Iron (ppm)	2.0 max	–	–	–	–	–
Copper (ppm)	0.05 max	–	–	–	–	–
Neutral oil (%)	–	–	–	98.5 min	99 min	–
$E_{1cm}^{1\%}$ 232 nm	–	3.0 max	2.1	–	–	–
Sulphur (ppm)	–	–	20	–	5.0	–

References 14 and 15.

refining of palm oil indicating the importance of conforming to each item in the more detailed specifications to achieve a satisfactory end product. The publication of chemical and physical characteristics of Malaysian palm oil (33) is welcomed as an aid to the interpretation of "good merchantable quality." More data will be needed to characterize the product now that so much further processing is being carried out in the country of origin to prevent fraudulent practice. This is elaborated by Rossell (Conference Proceedings). Despite modern technology, it is disappointing to note that the new Malaysian standard does not propose a reduction in FFA of the standard crude palm oil from the 5% contract level. As shown in Table X, a level of 3.5% is achieved as standard by at least one producer. It was also reported by Yong (36) in 1976 that the then-current standard quality Malaysian palm oil was typically 3% FFA with a range of ± 1%. High levels give more opportunities for malpractice, and do not provide an incentive to improve and bring palm oil into line with other premium oils.

A development in the UK has been the increased use of physical refining for processing palm oil. As a consequence, the crude oil quality constraints are more critical and the UK Seed Crushers and Oil Processors Association (SCOPA) have finalized a bleachability test, including steps similar to physical refining such as degumming, earth and hat bleaching, which is now felt to be suitable for contract purposes.

It is hoped to achieve national and international recognition via BSI and ISO. A shorter test introduced by PORIM called the "deterioration of bleachability index" is also under development. Bleachability still remains a prime fac-

TABLE IX

Contractual Quality/Country Standards/Crude Palm Kernel Oil

Contract	NIOP Rule 167/150	FOSFA 54	FOSFA 54	British Standard 652:1967	PORIM[c]
Source	Open	Malaysia	Ivory Coast	–	Malaysia
Quality	Not modified Unadulterated	GMQ	GMQ	Typical	Typical
FFA/lauric (%)	5.0[a]	5.0 max[b]	5.5[a]	–	–
	6.0 max[b]	5.5[a]	6.0 max[b]	6.0 max	–
Moisture and (%) impurities	1.0 max[b]	0.5 max	0.5 max	–	–
Flash point (F)	250 min	250 min	250 min	–	–
Iodine value	–	–	–	13-23	16.2-19.2
Lovibond color (1"cell)	–	–	–	1.5R 20 Y max	–
Saponification value	–	–	–	242-252	243-249
Unsaponifiable matter (%)	–	–	–	1.2 max	0.1-0.8
Refractive index (40 C)	–	–	–	1.449-1.451	1.4500-1.4518

[a]Arrival basis.
[b]Shipment basis.
[c]Reference 31.

TABLE X

Contractual Quality, Supplier/Country Specifications for Crude Palm Oil – Maximum Tolerances

Contract	FOSFA 80	NIOP Rule 173	Malaysian Standard (34) MS719: 1981		Harrison & Crosfield Standard	Harrison & Crosfield Lotox	SPB (35)
Source	Malaysia	–	Malaysia	Malaysia	Malaysia	Malaysia	Zaire
Quality	Crude unbleached GMQ[b]	Pure unbleached	Standard[b]	Special[b]	Standard	Lotox	Special prime bleach
FFA/palmitic (%)	5.0[a]	5.0[a]	5.0	2.5	3.5	2.5	1.0-2.5
Moisture and impurities (%)	0.5	–	–	–	–	–	–
Flash point (F)	250 min	–	–	–	–	–	–
Moisture (%)	–	–	0.20	0.20	0.18	0.18	0.1
Impurities (%)	–	–	0.05	0.05	0.02	0.02	0.002
Peroxide value (me)	–	–	–	3	5	3	5-20
Anisidine value	–	–	–	4	–	4	5-10
Carotene (mg/kg)	–	–	500-1000	500-1000	–	typical 650	typical 500
IASC bleach	–	–	–	–	2.8R 28Y	2.0R 20Y	2.0R 20Y (5¼")
Iron mg/kg	–	–	–	–	5	3	≤5
Copper mg/kg	–	–	–	–	0.2	0.2	≤0.1
$E^{1\%}_{269}$	–	–	–	–	–	≤0.3	–

[a]Open. Typical shipment analysis (basis arrival) NIOP set at 5.0 maximum.
[b]Shipment basis (27) contains guideline characteristics.

tor of GMQ palm oil and a more sensitive test than the current IASC test is needed.

Copra and Coconut Oil

The most significant paragraph in the report of the 1959 working party on copra quality and grading emphasizes moisture content as the most important factor as nothing else can compensate for inadequate drying at source (37). It is said to be easy to produce a dry stable product. More recently, Cornelius (38) in a review on coconuts gives further detail on drying conditions which can lead to case-hardened, discolored copra with a burnt odor and rubbery texture. Drying of immature nuts can also give rubbery copra which is difficult to process, leading to high residual oil in the expelled cake (39). The difficulty in applying grading systems at source lies in the variety of drying methods used, the fact that production is largely in the hands of smallholders and trade is very competitive. As shown in Figure 1, there has been a marked decline in the exports of copra with a rise in the localized crush. Table XI summarizes the contractual quality of copra and it is noted that the high maximum levels of FFA are also rejection levels and indicate the variable quality to be expected with the product. Table XII records the quality basis of trade in coconut oil. There has been some improvement in Philippine copra quality over the last 3 years. Average moisture and FFA levels of shipments have both improved and in 1981 the variance also improved. Levels of FFA in exported crude oils were about 20% lower than oil in exported copra.

Sunflower Seed and Sunflower Oil

The contractual basis of trade in sunflower seed is shown in Table XIII. Oil moisture and admixture levels are defined and other criteria included in a GMQ clause in FOSFA contracts. The NCPA domestic grading in the USA is on a similar basis, but also includes FFA (on oil) and damaged seed. The presence of damaged seed merits downgrading to Sample Grade. Canadian sunflower seed grade requirements (10) (Table XIV), as with rapeseed, concentrate on physical condition and degree of soundness. The seed should be clean as the combine is set so high for harvesting (40) that foreign matter is most likely to be stems or leaves which are readily removed. It is not likely to present a problem and levels should be low. At physiological maturity, the seed dry weight, oil and neutral oil content are at a maximum with subsequent increase in FFA (41). Open pollinated varieties reach this stage 26 days after flowering and newer hybrid varieities flower more uniformly and reach the stage after 35 days. Seed variety is therefore of importance for uniformity of maturation but even more importantly, the seed structure can affect processing for oil (42). Higher oil content seeds with reduced hull content have increased wax levels in the hull and hulls are more difficult to separate from the kernels when processing (43). The relative hull:

TABLE XI

Contractual Quality: Copra

Contract	NIOP Rule 100	NIOP Rule 102	NIOP Rule 102 SA	FOSFA 1
Source	–	–	–	Philippine
Destination	N America Japan	Elsewhere	S America	–
Quality	FMQ	FMQ	FMQ	Sound FMQ
Unripe	Nil	Nil	Nil	–
Dirt, foreign matter	Nil	Nil	Nil	–
FFA/oleic (%)	3.5[a] 10.0 max	4.0[a] 10.5 max	5.0[a] 11.0 max	4.0[a] 10.5 max
Moisture	5.0[a]	4.5[a]	7.0[b]	4.5[a]
Oil color Lovibond (5¼" cell)	9R 50Y max	9R 50Y max	9R 50Y max	9R 50Y max

[a]Arrival basis.
[b]Shipment basis.

TABLE XII

Contractual Quality: Coconut Oil

Contract	NIOP Rule 156	FOSFA 54	FOSFA (SF)[d]	FOSFA (SF)
Source	Manila type crude	Philippine	Papua New Guinea	Ivory Coast
Quality	Unadulterated[c]	GMQ	GMQ	GMQ
FFA/lauric (%)	6.0 (oleic) 12.0 max	3.0[a] 4.0[b] max	1.0 –	3.0 4.0 max
Flash point (F)	250 min	250 min	–	–
Moisture and impurities (%)	–	1.0 max	0.5	0.5

[a]Arrival basis.
[b]Shipment basis.
[c]Original solid and fluid fatty acids in original proportions.
[d]Typical short form contracts.

kernel ratio in the seed has been recorded by Earle et al. (44) demonstrating that in 1968 the oilseed varieities of sunflower seed in the USA ranged from 22% to 28% hull content. In 1981, it was predicted that the hull content of the newer hybrids may eventually range from 17% to 22%. The proportion of hull present in the seed, and its ease of removal, is of major importance to the processor whose process may be geared to removing it.

The bulk density of the seed is also affected by variety or uniformity and this, of course, is relevant to plant design and throughput which, due to the bulky nature of the seed, requires larger conveyors than required for other seeds. The sort of variation experienced in the past is a minimum figure of 21 lb/bushel for No. 3 Canada seed and an average of 29.5 lb/bushel for the 1981 crop in North and South Dakota and Minnesota (45).

As with soybeans and rapeseed, FOSFA contracts do not separately classify damaged seed, relying for cover on the GMQ clause. Referring to Table XV listing the trading specifications for crude sunflower oil, it will be noted that waxes and/or foots are not included as a separate item. These are major problems for the processor. We have found that good quality oil has an average of 2 ± 2% foots by volume after settlement and are invariably light in color. Shipments have been encountered well outside these figures and as high as 25%. The phospholipid content of the oil varies from 0.5% to 1.0% (46) but more typical levels are 0.5-0.8%. When the moisture content is over 0.16%, over half the phosphatides can precipitate out on lengthy storage. It is believed that phosphatides in the oil act as crystal inhibitors and delay the precipitation of waxes. When the phosphatides are hydrated, this effect disappears and waxes are also deposited. We have found that variable wax contents have accentuated the foots problem and given rise to problems in dewaxing. The variation is further defined by Morrison (47) who found wax levels ranging from 0.008% to 0.044% in 5 samples of US oil.

There really does appear to be a case for marketing oil from decorticated seed as a separate entity, as over 80% of the wax in the oil comes from the hull. This could well resolve problems in France where the AFNOR method for analyzing oil content in the seed disregards the oil and wax content of the hull which is said to be as high as 0.4%. The reasoning is that the seed is processed either partially or totally decorticated in France and the waxes are without value. The contractual method of analysis based on ISO/R.659 includes waxes as "oil" and France has made representations to the EEC Seed Crushers and Oil Processors

TABLE XIII

Contractual Quality: Sunflower Seed

Contract	FOSFA 11	FOSFA 11A	NIOP Rule 110	NCPA Rule S1
Source	Open	US, Canada	US (export)	US (domestic)
Quality	GMQ	GMQ	Sound, sweet merchantable	Prime oilseed[c]
Oil tq (%)	40[a]	40[a]	√	40 min
Moisture (%)	10[b]	10	√	10 max
	12 max	12 max	√	
Admixture (%)	2[b]	2[b]	√	nil
	4 max	4 max	√	
FFA (% in oil)				1.8 max

[a]Arrival basis.
[b]Shipment basis.
[c]Free of off-flavor and odor, field and heat damage.
√ = To be included by agreement.

TABLE XIV

Canadian Sunflower Seed Grading Requirements: Maximum Tolerances (%) Canada Grain Act 1972

Grade	Degree of soundness	Cracked hulled seed	Heated rotten musty	Dockage	Moisture
No. 1 Canada	Well matured, sound, sweet, uniform size	2	free	2.5	9.5
No. 2 Canada	Reasonably well matured, sweet, free from damaged kernels	5	free	2.5	9.5
No. 3 Canada	May have frost or other damage. May have natural odor of low quality seed but not sour, musty, rancid or contaminated odor.	10	free	2.5	9.5
Sample	Defect				
Canada account (defect)	> 2.5% admixture (other grains) earth pellets, stones > 0.5% *Sclerotinia Sclerotiorum* > 2.0% heated				

Damage: cracked, hulled, heated, rotted, very immature insect damage or other. Cracked and hulled are broken and whole seeds that are hulled, not seeds with cracked hulls.

TABLE XV

Contractual Quality: Crude Sunflower Seed Oil

Contract	FOSFA[a] 53	American Fats and Oils[a] Rule 14 - Export	NCPA[b] Rule 5
Source	Open		USA
Quality	GMQ	Pure from FAQ Sunflower seed	Pure from US seed
Process	–	Pressed or solvent	Pressed or solvent
FFA/oleic (%)	2.0 3.0 max	2.0 max	3 max
Moisture and impurities (%)	0.5 max	–	–
Moisture and volatile matter (%)	–	0.5 max	0.5 max
Impurities (%)	–	0.3 max	–
Flash point (F)	250 min	250 min	250 min
Color refined bleached (5¼" cell)	–	2.5 red max	2.5 red max
Halphen test	–	Negative	–
Unsaponifiable matter (%)	–	1.3 max	–
Saponification value	–	188-194	–
Linolenic acid (%)	–	1.0 max	–
Neutral oil loss (%)	–	–	7.5 max

Note: FOSFA set quality and flash point only. Other values are typical.
[a]Shipment basis.
[b]National Cottonseed Products Association.

Federation to try and amend the ISO method. On the other hand, seed is generally not yet decorticated in the UK. In present circumstances, until such time as low wax content seed becomes available, oil from decorticated seed should be identifiable and allowed to reach a fair market value. A new plant in North Dakota is designed to remove 65% of the hulls from the seed to produce high protein meal and also includes a degumming step to reduce the foots problem (48).

As one of the important attributes of sunflower oil is its high level of linoleic acid, it should be noted that oil from seed grown north of the 39th parallel has an average level of 68% and southern seed oil, an average of 44%. Over 95% of the US crop is grown in the Dakotas and Minnesota region where the range from North to South was 72-64% linoleic acid in 1981. In the UK, there is a demand for 66% minimum linoleic acid content, a requirement not yet directly recognized in seed or oil contracts.

CRUSHING TECHNOLOGY AND OIL QUALITY

The most valuable part of the oilseed is the oil and the amount present by analysis is defined as the hexane or light petroleum spirit extractable matter under the conditions of the test procedure. To the chemist, crude oil is a mixture of glycerides, free fatty acids, glycerol, coloring matter and natural antioxidants, sterols, trace elements, foots and water. Foots can further be defined as mixtures of phospholipids and their complexes and waxes. When the oil is refined, the desired end product in most cases is the mixture of neutral glycerides, with perhaps traces of color and antioxidant. In most instances, the other constituents would be better left with the meal, with the exception of soy lecithin, or reduced and maintained at low levels in the seed.

Gustafson (49) has discussed the controls necessary in storage and handling of oilseeds. Of particular interest is the 3.2% breakage of soybeans, which can occur when tipping into a soybean layer in 100 ft silos, and raised moisture levels, both of which can lead to increases in FFA. The relation of moisture content to relative humidity for soybeans, rapeseed and sunflower has been reviewed by Pixton (50) who includes tables over a range of temperatues up to 35 C. In a carefully designed series of experiments, Mounts et al. (51) examined the transportation of two separate soybean shipments from the USA to Tilbury and Rotterdam, respectively. Oil, protein, splits (10.4%) and moisture content were unchanged in transit except for an unexplained drop in moisture of 1.5% on the Rotterdam shipment. The Tilbury shipment took 6 weeks in transit, and original samples were divided into whole beans and splits followed by extraction and analysis of the oil. There was a significant increase in FFA (1.0%) and iron content (2.1 ppm) and a large increase in nonhydratable phosphatides after degumming (from 37 to 183 ppm). The problem with FFA and iron content was traced to the split beans which have a disproportionate deleterious influence on the oil quality. Evidently, damage in the form of splits is a more serious defect than was formerly realized and a reappraisal of levels in the grades is justified, based on these results.

The reduction of glucosinolate levels in canola seed has not eliminated the problem of sulphur in rapeseed oil (52). Provided sound seed of low moisture content is used together with a minimum amount of water and heat and a slightly low extraction yield, low sulphur levels will be achieved. Prepress expelled oils have lower sulphur levels than extracted oils (53).

The degree of extraction as measured by the residual oil in the meal can influence oil quality. Karnofsky (54) demonstrated this in a classical paper recording factors affecting total extractables in soybeans. Down to 2.0% oil, the refining loss was 6%. Extractables between 0.25 and 1.1% oil had 81.5% refining loss. More recently, Wiegand (55) has shown that raising the flaking temperature of rapeseed gives a higher chlorophyll level and a darker colored oil, with lower residual nonhydratable phosphatides (NHP) in the expelled and extracted oil. The concentration of phosphatides, FFA and oxidized lipids increased with lower residual oil in meal after extraction. His plant appears to target for 2-4% residual oil in meal and, in fact, many plants operate on high oil content seeds for considerable periods at higher levels than 0.8% oil ex toaster (which is usually quoted for soybeans) as increased throughput is often preferable economically (56).

There is no doubt that the increase in physical refining and the demand to extend the process to oils other than palm and tallow has caused technologists to widen horizons, as shown by the development of the ALCON process (57-60). It has been demonstrated that conditioning soybean flakes from sound beans and inactivating the enzymes prior to extraction doubles the lecithin yield and reduces the NHP to levels acceptable for physical refining, i.e., less than 10 ppm phosphorus using US No. 2 yellow grade beans. Adjustment of drainage intervals in the extraction cycle can counteract the slightly increased residual oil content from the agglomerated flakes. After earth bleaching, reducing to 5 ppm phosphorus or less, the oil can be physically refined. However, poor soybean quality caused a rise in FFA and phosphorus in the degummed oil although the oil could still be physically refined with increased bleaching earth pretreatment levels. A premium may be sought for ALCON oil over the normal degummed oil which contains 200 ppm phosphorus.

The Krupp VPEX^r process (61) producing energy savings by prepressing whole, uncooked seed, claims improved oil quality on rapeseed with improved color and Totox values. This process should be watched with interest as the demands on seed quality are apparently not so stringent.

An even more radical move such as changing to isopropanol as solvent in place of hexane would produce significant quality benefits (62) by reduced FFA and phosphatide levels, although the development is in its early stages.

Decortication of seed, usually done to increase protein levels in the meal, can also affect oil quality, particularly in the case of sunflower seed. Waxes and pigments in the hull contribute to varying levels of foots and can cause darkening of the oil at high prepressing temperatures. It is considered perferable to leave a proportion of hulls with the kernels to assist processing. In North Dakota, of two new plants built since 1980, one decorticates and the other partially decorticates the seed. A third plant, scheduled for completion by the end of 1982, will decorticate and degum the oil. In the UK at present, seed is not decorticated. The end result is a variable level of foots settling from the crude oils, causing problems in handling and dewaxing. Contracts do not specifically cater for this variation.

It is evident that choice of process can produce a quality variation in the crude oils and that the processing method, as well as adjustment of variables within a given process, can have a considerable impact. There are also hidden energy savings in more careful seed handling from field to factory. It is, nevertheless, the quality of the seed which is the major determining factor in oil quality.

DESIRABLE ATTRIBUTES IN OILSEED SPECIFICATIONS

Natural products vary in quality and the variation about the mean can be quite wide and beyond the skill of the processor to correct without incurring financial penalties, or indeed, downgrading of the end products. The specification should identify significant readily measured variables which affect quality and value of the end products and allow for a reasonable period of storage. The crop year should be defined in a description as "new crop" or "old crop" or by year since the rate of degradation can increase with age. The source country is also important, as climate can affect the fatty acid composition.

The International Standards Organisation Committee ISO/TC/34/SC2 are currently drafting standards which, at the present stage, include the following criteria: impurities, moisture and volatile matter, minimum hexane extractable matter (oil) at a stated moisture content, moisture and volatile matter as maximum (and for sunflower minimum as well), FFA (on oil basis), erucic acid maximum for low erucic acid rapeseed, and minimum for high erucic acid rapeseed. Common to each specification are sensory and hygiene characteristics defining the seed as "sound, ripe, without foreign odor (phyto-pharmaceutical products, etc.) or any indication of change in condition, (musty, rotten, burnt smell, etc.). Live insects absent."

The good news for the processor in these standards is the inclusion of oil content and FFA in the oil; the bad news is the omission of a tolerance for damaged seed and a chlorophyll level for rapeseed. The sensory characteristics imply an ideal condition not in accordance with practicalities.

"Impurities" does not include seed damaged in any way, it only includes excess hulls and very fine meal particles apart from seed not of the basic species and foreign matter. The EEC intervention standard for rapeseed includes a clause recognizing damage, i.e., "the seed must be free from abnormal smell, especially mold, with not more than 2% immature, sprouted, mechanically damaged split or empty seeds." Although the processor would prefer seed to be completely free from damage, it is preferable to recognize it and define an acceptable level. The importance of chlorophyll levels in rapeseed has been discussed, and Daun's recommendation of 12 ppm maximum in the seed should be included.

More consideration should be given to the inclusion of minimum moisture levels in addition to maxima. When the seed is too dry, it is more friable and more fines are produced when it is rolled. It would also be an additional safeguard against heat damage by focussing more control on the drying process. Protein content of the seed is of greater relevance with low oil content seeds, e.g., soybeans. There is evidence, however, (63), of substantial increase in protein content in field and storage damaged soybeans, indicating that a cautious approach is required.

Bulk density of the seed affects storage capacity in silos as well as plant throughput and the wide range in the case of sunflower seed merits recognition. On the other hand, single seed size, and more particularly, uniformity of seed size is important with small seed such as rapeseed. Small seed can readily pass through the rolls escaping attrition and lead to high residual oil results. In this context, it is noted that UK rapeseed is much larger than Canadian and Danish seed (1.92 and 1.44 mm diameters). Small sunflower seeds are more difficult to decorticate and the hulls have a higher protein content than large seed. Size grading before decorticating the large seed is the best compromise (64), but more uniformly sized seed would be preferable.

There exists presently, a wide inconsistency in the grading and trading quality of oilseeds. The ISO approach provides teeth to fill a gap but the bite will be missing unless there is full consultation and acceptance by all the various country and trade associations concerned.

DISCUSSION

The recurring theme with each oilseed is the deleterious effect of damaged seed. This has been recognized in the USA and Canada for some years and their grading systems take it into account. In the current review of US soybean grades, the permitted levels of splits should be appraised more critically based on recent work by Mounts. The level of 12 ppm maximum chlorophyll content in Canadian rapeseed proposed by Daun as a replacement for the green seed count should be expedited and receive international recognition as a means of overcoming a major quality deficiency. The benefits of double zero rapeseed as regards sulphur levels in oil could be minimal unless seed damage is restricted. Laboratory extracted oil from sound seed contained no detectable sulphur regardless of glucosinolate level (53). The level of damaged palm kernels in shipments has been rising in the absence of contractual restrictions. There would appear to be justification for introducing damaged seed into contracts at a declared level with appropriate penalty clauses.

The work of Ismail on the deleterious effects of dockage on quality of rapeseed oil is well based and the implications sufficiently serious to revise dockage levels in the Canadian rapeseed grades down to a 1% level.

The crusher has a limited ability to improve oil quality from a given seed. Temperature restriction, degree of extraction and decortication (sunflower seed) are the main controlling factors with a given solvent. Cold pressing, as, for example, with the Krupp VPEX^r process, may prove to be less sensitive to seed quality. Experience will tell. The large increase in NHP during shipment of soybeans to Europe, points to a requirement for further research, as the results could affect the physical refining of soybean oil even using the ALCON process as well as traditional processes.

It is considered that the basic quality factors in international trade of oilseeds should be oil content, moisture and volatile matter (both maximum and minimum levels), admixture, damaged seed and FFA (on the oil). Other items should be added to specific seeds, e.g., erucic acid and chlorophyll to rapeseed contracts. Furthermore, a basic quality clause should be established common to all contracts based on the EEC intervention standard for rapeseed and the ISO sensory and hygiene characteristics. This would not replace the GMQ clause, but would clarify certain aspects promoting recognition of the fact that oilseeds are mostly used as an ingredient basis for human food and may be processed in a food factory complex.

The rising demand for crude oils suitable for physical refining can be met partly by improvement in seed quality and handling, and partly by process changes. Additional control test methods such as the UK SCOPA bleachability test for palm oil may be required in addition to phosphorus levels which have been suggested for soybean oil. The recent deterioration noted in palm kernel oil quality due to the presence of carotene, whilst not yet of major proportions, is a disturbing trend which should be checked.

Other trading considerations suggested are (a) separate marketing of crude oil from decorticated sunflower seed with reduced wax levels, and (b) an indication of linoleic acid content in sunflower seed specifications.

The introduction of a standard grade Malaysian palm oil at 5.0% FFA is a retrograde step out of line with previously published producers standards set at 3 ± 1%. The logic of this move remains an area for speculation.

REFERENCES

1. Young, F.V.K., Proceedings of the 2nd ASA Symposium on Soybean Processing, American Soybean Association, Antwerp, 1981.
2. Report on 57th World Congress of IASC, JAOCS 58:656A (1981).
3. Unilever Oils and Fats Statistics 1978/1981, Unilever Merseyside Ltd., Bebington, Wirral, UK, 1982.
4. Airey, D., Chem. Ind. 13:453 (1982).
5. Faure, E., JAOCS 53:235 (1976).
6. Federation of Oils, Seeds and Fats Associations Ltd., FOSFA Manual, London, 1982.
7. National Soybean Processors Association, Year Book and Trading Rules 1981-82, Washington, DC, 1981.
8. International Association of Seed Crushers, Oilseeds, Oils and Fats, 3rd Edn., London, 1980.
9. USDA Federal Grain Inspection Service, Grain Inspection Handbook, Book 11, Washington, DC, 1980.
10. Canadian Grain Commission, Grain Grading Guide, Winnipeg, 1980.
11. Norris, F.A., Proceedings of the Quality Control Seminar in Soybean Crushing Plants and Soybean Oil Processing Plants, American Soybean Association, Brussels, 1979.
12. Thomas, A., Proceedings of the 2nd ASA Symposium on Soybean Processing, American Soybean Association, Antwerp, 1981.
13. Brekke, O.L., Handbook of Soy Oil Processing and Utilization, American Soybean Association and AOCS, St. Louis, MO, 1980, p. 377.
14. List, G.R., Ibid., p. 355.
15. 1978/79 Resolutions, American Soybean Association, St. Louis, MO, 1978, p. 6.
16. Frahm, D.G., Including Protein and Oil in New Soybean Standards, American Soybean Association, Hudson, IA, 1978.
17. McNeil, M., Soybean Dig. Feb:90 (1982).
18. Leysen, I.R., Proceedings of the Quality Control Seminar in Soybean Crushing and Soybean Oil Processing Plants, American Soybean Association, Brussels, 1979.
19. Dahlen, J.A.H., JAOCS 50:312A (1973).
20. Craig, B.M., Proceedings of the International Rapeseed Conference, Ste. Adele, Rapeseed Association of Canada, Winnipeg, 1970, p. 170.
21. Daun, J.K., JAOCS 59:15 (1982).
22. Canadian Government Specifications Board, Rapeseed Oil, Low Erucic Acid, Crude and Crude Degummed, CAN 2-32-300M-76, CGSB, Ottawa, 1976.
23. Ismail, F., N.A.M. Eskin, and M. Vaisey-Genser, Canadian Canola Research Summary No. 1, Canola Council of Canada, Winnipeg, 1980, p. 49.
24. Wiegand, J.G., Proceedings of the 5th International Rapeseed Conference 2, Malmo, 1978, p. 314.
25. Teasdale, B.F., Ibid. p. 334.
26. Cornelius, J.A., Prog. Chem. Fats Other Lipids, 15:5 (1977).
27. Hartley, C.W.S., The Oil Palm, Longmans, London, 1967.
28. De Ramecourt, B., JAOCS 53:256 (1976).
29. Pritchard, J.L.R., Tropical Sci. 11:103 (1969).
30. Cornelius, J.A., Proceedings of the Tropical Products Institute Conference, London, 1965, p. 105.
31. Siew, W.L., and K.G. Berger, Porim Tech. 6:5 (1981).
32. Young, F.V.K., Ibid. 1 (1981).
33. Tan, B.K., and C.H.O.H. Flingoh, Ibid. 3 (1981).
34. Malaysian Standard Specification for Crude Palm Oil, MS 719: 1981, Standards and Industrial Research Institute of Malaysia, Shah Alam Selangor, 1981.
35. Loncin, M., Fette, Seifen, Anstrichm. 76:104 (1974).
36. Yong, M.L., Symposium on Utilization of Palm Oil, American Oil Chemists' Society, Champaign, IL, 1976.
37. Cooke, F.C., Report of working party on copra quality and grading, Colombo, 1959.
38. Cornelius, J.A., Tropical Sci. 15:15 (1973).
39. Malabringo, P., JAOCS 54:485A (1977).
40. Pierce, R.M., Ibid. 47:248A (1970).
41. Robertson, J.A., G.W. Chapman and R.L. Wilson, Ibid. 55:266 (1978).
42. Morrison, W.H., D.E. Akin, and J.A. Robertson, Ibid. 58:969 (1981).
43. Scott, J., Oil Mill Gazet., 85:10 (1980).
44. Earle, F.R., C.H. Vanetten, T.F. Clark and I.A. Wolff, JAOCS, 45:876 (1968).
45. Sunflower Crop Quality Report, National Sunflower Association, ND, 1981.
46. Arutyunyan, N.S., V.M. Kopeikovsky, and Mkhitaryants, Proceedings of the 7th International Sunflower Conference, Krasnador, USSR, 1976, p. 478.
47. Morrison, W.H., and J.A. Robertson, JAOCS 52:148 (1975).
48. Ruckenstein, C., Fette, Seifen, Anstrichm. 84:504 (1982).
49. Gustafson, E.H., JAOCS 55:751 (1978).
50. Pixton, S.W., Tropical Stored Products Information, Tropical Products Institute, Slough, UK, 43:16 (1982).
51. Mounts, T.L., G.R. List and A.J. Heakin, JAOCS 56:883 (1979).
52. Anon., Ibid. 58:723A (1981).
53. Daun, J.K., and F.W. Hougen, Ibid. 53:169 (1976).
54. Karnofsky, G., Ibid. 26:564 (1949).
55. Wiegand, J.G., Proceedings of the 5th International Rapeseed Conference, Malmo, 1978, p. 314.
56. Norris, F.A., Bailey's Industrial Oil and Fat Products, Vol. 2, 4th edn., Wiley & Sons, New York, NY, 1982, p. 227.
57. Kock, M., DGF Vortragstagung, Kiel, 1980.
58. Penk, G., Ibid., 1980.
59. Ong, J.T.L., Proceedings of the 2nd ASA Symposium on Soybean Processing, American Soybean Association, Antwerp, 1981.
60. Penk, G., Ibid., 1981.
61. Krupp, G.m.b.H., 2100 Hamburg 90, Germany, 1981.
62. Sullivan, D.A., B.D. Campbell, M.F. Conway, and F.N. Grimsby, Oil Mill Gazet. 86:24 (1982).
63. Robertson, J.A., W.H. Morrison and D. Burdick, JAOCS 50: 443 (1973).
64. Igolcenko, M.I., and V.M. Kopejkovsky, Pishch. Teck. 31:12 (1962).