Our Experiences in Processing Maize (Corn) Germ Oil

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ABSTRACT

This paper discusses the properties and composition of corn oil. Influences of processing steps on oil quality are described, along with alkali and physical refining, degumming, bleaching, dewaxing, deacidification-deodorization. A new method for wet degumming-bleaching and deacidification-deodorization is presented. Flowsheets and other data are given for a new 150 metric tons per day of corn oil plant.

Corn oil is produced as a byproduct of two of the corn-using industries: the starch industry, in which maize germ is obtained in the wet degermination process (the oil content of the germ obtained in this process is ca. 50%); and the corn meal industry which produces hominy, grits, corn flakes, etc. Here the germ is obtained in the dry degermination process and contains from 10% to 24% oil.

Corn oil is a minor commodity in the oil market. The increase in use of corn oil as salad and cooking oil, and in margarine, is due to the awareness of the importance of polyunsaturated fatty acids in the diet, its tocopherol content and oxidation stability. Wide publicity has been given to the nutritional properties of corn oil as a good source of essential fatty acids. Corn oil production has increased markedly due to the increased consumption of high fructose corn syrup produced from the corn starch.

Corn oil composition depends on the seed type and climatic conditions. It is known that oil obtained from maize grown in the north has a higher iodine value (IV) than the same type grown farther south.

The average analysis of crude maize oil processed in South African factories built by H.L.S. Ltd. is 3-6% free fatty acids (FFA), iodine value of 110-125, and 300-1000 ppm phosphorus.

Oil from different corn, can be expected to have different compositions. There is a direct relationship between the iodine value of corn oil and its linoleic acid content. The equation is Y (%C18) = 0.95 (IV) - 61.8. Regarding the phospholipids of corn oil: more than 50% of them contained inositol, the rest being glycerylphosphatidylcholine, phytoglycolipid, etc.

Corn oil contains traces of waxes, which are esters of myricil alcohol with tetracosanoic acid. According to literature, ceryl alcohol esters were also identified. The melting point of these waxes is 81-82 C.

An important component of the unsaponifiable fraction of corn oil is tocopherol (ca. 0.1%), mainly γ-tocopherol which has antioxidant potential activity. The main pigments in crude corn oil are xanthophylls and carotenes.

TABLE I

Fatty Acid Composition of Maize Oil

Fatty acid	Codex Alimentarius (tentatively adopted) (%)	South Africa (%)	USA (%)
C12 (Lauric)	0.1	0.4	0.1
C14 (Myristic)	1.0	0.2	0.2
C16 (Palmitic)	8.0-19	11.5	11.0
C16 (Palmitoleic)	0.5	0.1	
C18 (Stearic)	0.5-4	2.0	2.0
C18 (Oleic)	19.0-15	38.7	24.1
C18 (Linoleic)	34.0-62	44.3	61.9
C18 (Linolenic)	2.0	1.1	0.7
C20 (Arachidic)	1.0	0.6	
C22 (Behenic)	0.5	0.1	
C22 (Erucic)	0.5	0.3	1.7
C24 (Lignoceric)	0.5	0.3	

TECHNOLOGICAL PROCESSING

The method used to obtain the maize oil, the history of the grain, the storage and handling of the germ—all have an important influence on the quality of the crude oil. In our experience, wet milled germ must be processed by prepressing extraction. Some large starch factories also have final presses which give cakes with 6% oil.

The germ obtained by dry degermination can be direct-extracted in solvent extraction plants. Preparation of germ with a small percentage of fines consists of the usual cracking, conditioning and flaking. For separated dry germ with a high percentage of fines (as in South Africa), it is necessary to pellet the germ before extraction.

For the direct solvent extraction of the germ, in the form of pellets or flakes, we developed the TOM extractor which has been described at previous AOCS meetings so we will point out only its main advantages.

In the TOM extractor, we turn over the material at its half-way point inside the extractor (Fig. 1). This inversion mixes the material and destroys the impermeable layer which the fines form at the top of the material bed. The starch content of the germ is not sufficiently gelatinized and this makes the extraction more difficult. For this reason we try to work with a shallow bed of material in the basket. The starch also absorbs more hexane than normal oilseed flakes. In the TOM extractor, we can work in the beginning by immersion and in the second stage of extraction, continue with percolation. We have a large number of extracting stages and good separation of the various miscella concentrations. To obtain a clean miscella, a multiple system of hydroclones is introduced for materials with a high percentage of fines.

Several years, in cooperation with an oil plant in Durban, South Africa, belonging to the Tiger Oats Group, we developed and supplied a physical refining plant to deacidify maize oil with a high fatty content (average 23.6%).

After normal wet degumming, the oil was heated and during continuous mixing, 0.3-0.5% phosphoric acid (conc. 85%) was added. At 90 C, 2% bleaching earth was introduced and the temperature brought to 110 C under vacuum for 20-25 min. After cooling and filtration, the oil was introduced into the deacidifier-deodorizer with ca. 5% of direct steam. Over 220 C, the fatty acids started to distill. The final temperature of distillation was 250 C when

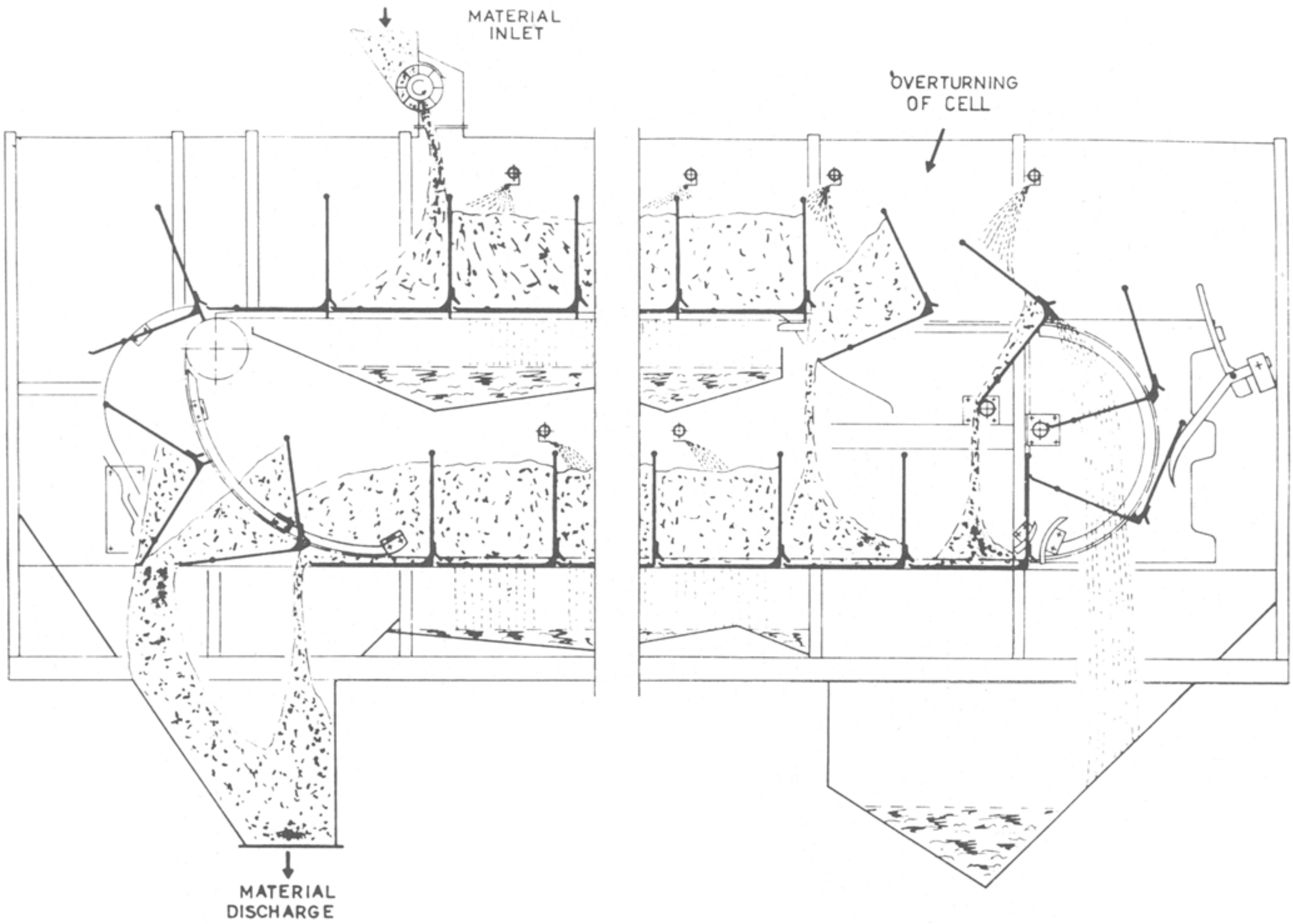

FIG. 1. TOM extractor.

deodorization started. Using this system, the FFA could be decreased to 0.3-1%.

After this operation, it was necessary to postrefine the oil. It was very difficult to neutralize this oil which had a high monoglyceride content. We continued our research and in the last 2-3 years, developed a new, patented method of special wet degumming (SWD) which eliminated the need to postrefine and directly gives deacidified-deodorized oil.

The main advantage of the SWD system is reduced phosphorus and metal content of the oil. The result is that in the bleaching process the amount of bleaching earth required is no larger than the amount usually needed for bleaching after neutralization. In this case, the yield of refined oil is better and there are no extra expenses for bleaching earth. Also, the more complete elimination of phosphorus and metals makes the stability of the oil similar or better than with classical refining methods.

The success of this new method is attributable to several factors: a reactive food-grade acid, the proper temperature of reactions, optimum retention time and an efficient, inexpensive flocculating agent.

H.L.S. is now building, together with Epic Oils, a 150 ton/24 hr plant for maize oil. The special wet degumming (SWD) and bleaching system for this plant is shown in Figure 2.

This process begins with pumping the oil into the system through a heat exchanger, which brings it to the proper temperature. Other exchangers along the way maintain the temperature of the oil at the correct levels. In the first mixer, the oil is treated with a food-grade acid proportioned by a dosing pump. Efficient agitation insures total contact between the acid and the oil. When the action is completed, the oil is pumped to the hydration mixer where a second dosing pump introduces the proper amount of aqueous flocculant solution. After extensive mixing, the treated oil flows into a holding tank where slower precipitation is completed and the floccules grow large and heavy.

The next step is the centrifuge where the solids are separated. The precipitated gums can be dried and sold to manufacturers of commercial lecithin.

The degummed oil goes to the drier where all water is removed. Part of the oil enters a mixing tank where a predetermined quantity of bleaching clay is added. The slurry and the degummed oil are pumped to the continuous bleacher and agitated under vacuum for about half an hour before filtering. A pair of vertical filters separates the bleaching earth from the oil—one is in operation while the other is being cleaned.

The filtered oil is cooled, and passed through a safety filter to remove any remaining traces of clay. It must now be deacidified and deodorized. Although there are many ways and systems to accomplish this final step, the H.L.S. continuous deacidification and deodorization system (CDD) has special and unique advantages (Fig. 3) the main

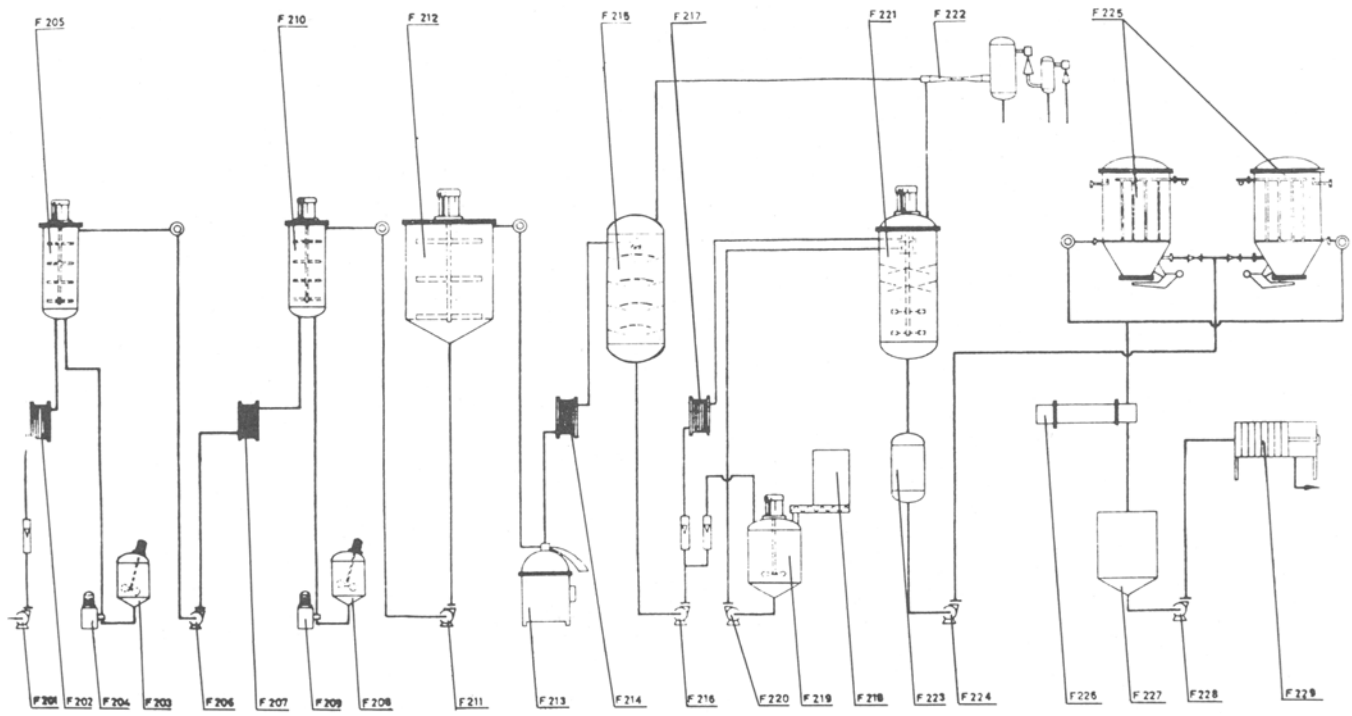

FIG. 2. Special wet degumming (SWG) and continuous bleaching.

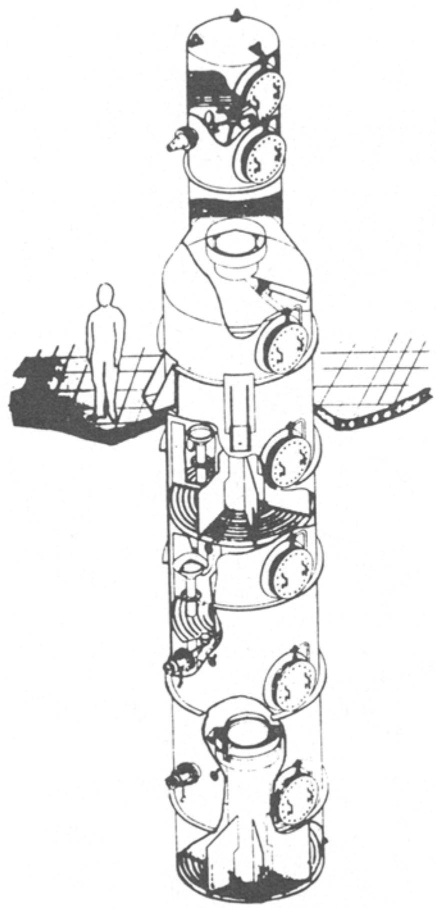

FIG. 3. Continuous deacidifier/deodorizer.

one being steam and energy economy, as a result of very efficient heat exchanger which cools the final product as it heats the incoming oil, and a low amount of stripping steam accomplished by highly effective steam dispersion through a large number of nozzles, with a low oil level preventing coalescence of the steam bubbles.

These two factors bring the total steam consumption to 100-120 kg/ton of oil (with cooling water temperature of 20-25 C). Other features of the H.L.S. deacidifier-deodorizer are continuous and semicontinuous operation in the same unit because of the special timing valves which allow working semicontinuously, or overflow pipes which allow the bypassing of the closed valves. This feature enables rapid changes of oil stocks.

We have introduced dividing walls which enable the system to operate in the continuous way on the principle of "first in, first out".

To illustrate use of the newly developed physical refining system, results of processing in our pilot plants of maize oils from several sources are shown in Tables II and III.

These examples show that with this new method we obtain good oils (with better yields also) for maize oils with high acidity. From oil with 8.4-14% FFA corresponding to a Wesson loss of 10-16%, under the best conditions, the results after classical (caustic) refining are 85-75% refined oil. The same oil, after steam refining, gives us 89-80% refined oil.

Other advantages of physical refining: no ecological problems as with soapstock splitting; better quality of fatty acids; and lower initial investment in equipment—there is no need of neutralizing and washing centrifuges, no need for splitting section. Only one centrifuge is required for the separation of the gums.

DEWAXING AND WINTERIZATION

Maize oil has small amounts of waxes which solidify at low

TABLE II

Maize (Corn) Oil from Dry Degermination—South Africa

Sample:	D	N	R	E
FFA (%)	8.7	14	8.4	18
P (ppm)	50	319	391	323
Lovibond (1")	Y=79, R=7.1	Y=35, R=4.4	Y=70, R=7.4	Y=50, R=4.7
After SWD and bleaching (2%)				
P (ppm)	0.9	7.6	2.9	2.55
After deacidification-deodorization				
FFA (%)	0.05	0.02	0.07	0.04
PV (meq/kg)	0	0	0	0
Lovibond (1")	Y=20, R=2.7	Y=15, R=1.9	Y=20, R=2	Y=30, R=2.2

TABLE III

Maize (Corn) Oil from Wet Degermination

Source:	Israel	Israel	Belgium	South Africa
From:	Press	Extraction	Extraction	Extraction
FFA (%)	4.4	4.8	1.79	2.1
P (ppm)	185	180	640	285
Lovibond (1")	Y=40, R=5.5	Y=40, R=9	Y=45, R=10.5	Y=40, R=5
After SWD and bleaching (2%)				
P (ppm)	4.8	5.2	2	2.85
After deacidification-deodorization				
FFA (%)	0.03	0.04	0.02	0.03
PV (meq/kg)	0.1	0	0	0
Lovibond (5¼")	Y=30, R=4.1[a]	Y=14, R=0.9	Y=6, R=0.9	Y=15, R=1

[a]Color fixation by excessive temperature in cookers.

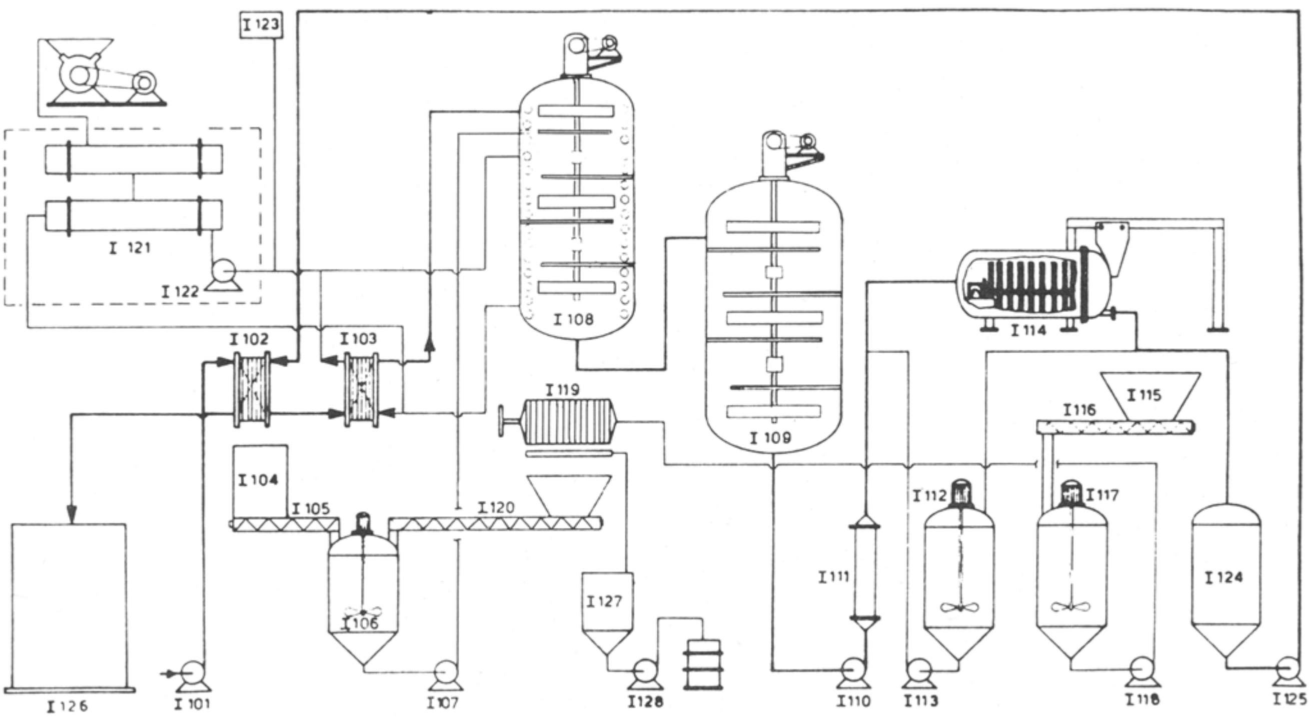

FIG. 4. Continuous winterizing.

temperatures and cause the oil to be turbid. Recent research on the triglyceride structure of corn oil showed that no triglyceride fraction that consisted wholly of saturated fatty acids was obtained and only a small percentage of disaturated triglycerides was found. As average, the triglyceride structure of corn oil can be represented as: S3 = 0, S2U = 2.2, SU2 = 40.3, U3 = 57.5.

Although the amount of disaturated triglycerides is quite small, it also contributes (in addition to the waxes) to the turbidity of the oil at low temperatures, and therefore has to be eliminated as well.

The dewaxing and winterizing of maize oil is difficult. In the new plant for Epic, we have installed our winterization system which is shown in Figure 4. The main conditions for winterization are: clean, degummed and dry oil—for this reason we place the winterizing after bleaching and before deacidification; optimum oil cooling temperature and low temperature difference by cooling to permit formation of filterable crystals; maturation after crystallization before filtration; and a suitable filter—we prefer the horizontal tank filters.

DESCRIPTION OF PROCESS

The bleached oil is precooled in a plate-type heat exchanger using the cold filtered winterized oil as the cooling media. Then it is further cooled in a plate type cooler using glycol solution as chilling agent. The chilled oil is introduced into the continuous crystallizer where it is cooled at a controlled rate to the optimum crystallization temperature while being gently agitated. A certain amount of filter aid (Kiselgur) is added to the crystallizer in the form of slurry which was prepared in a special mixing tank. This powder serves as crystallization nuclei and facilitates the oil filtration. After passing the crystallizer, the oil is introduced into the maturator in which the crystals get their final form suitable for filtration. Before filtration, the oil is heated somewhat to accelerate filtration rate.

The filter aid can be recuperated and reused. For this an additional filter is provided in which the powder is separated from the waxes and the stearines. After this separation, the waxes and stearines can be used in the margarine industry. In our pilot plants, we have also obtained good winterization of maize oil by crystallizing the oil with a wetting agent together with magnesium sulfate.

Although corn is one of the principal crops in the world, only a small part of it is used for producing maize oil. We notice an increase in the production of maize oil, but it is still not significant. The developing of alcohol plants for fuel from corn could contribute to the expansion of degerminating and oil production. Today the technology for processing maize germ and oil is sufficiently advanced to be able to handle the increased production of this premium oil.