Feature Article

Mongana Basics: Part 24 - General Conclusions**

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The results of four years of research can be considered as extremely satisfactory. They are reviewed below.

Oil Received at the Factory

The assessment of mill efficiency through analysis and accurate determination of losses occurring at the various stages of the process is preferable to the use of the oil content of bunches as determined by bunch analysis. It follows that control of fruit bunch ripeness becomes necessary. This control is based upon the number of detached fruits from or on the number of empty sockets found on bunches upon reception at the mill.

In the estimation of losses, basculators are used for the measurement of losses. They can also be used for the measurement of effluents, nuts as well as kernel production. The determination of the oil content of wastes (stalks, fibre, nuts and sludge) can be carried out by the so called azeotropic method.

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The oil content of bunches can be computed from the losses and the extraction ratio.

Sterilisation

The study of the mechanism of sterilisation has made it possible to determine the operating conditions leading to perfect stripping and optimum conditioning for subsequent treatment of the digested mash and the nuts. Sterilisation consists in maintaining bunches at a specific temperature for a specific period of time. In order to attain that temperature within a relatively short time, special precautions should be taken. In practice, they are linked to deaeration, which can be achieved by steam sweeping, multiple pressure releases (mixing and diffusion) and by continuous steam bleed off during sterilisation. The rate of penetration of heat is highest when these procedures are combined.

Extraction

Extraction depends primarily upon the fruit composition, that is the proportion of pericarp in the fruit. In the case of a pericarp content of 40%, the centrifugal extraction process leads to poor efficiency and it does not seem possible to improve it in a simple way. The wet extraction process

gives a good efficiency with this type of fruit. In the case of a pericarp content ranging from 50% to 60%, the centrifugal extraction process permits under well defined condition to obtain a press cake of low oil content.

In the case of fruit with a high pericarp content, particularly the latest selections of S x P (*Dura* x *Pisifera*), the continuous press is the preferred choice. The optimum operating conditions were determined. The advantages of this over other extraction processes are numerous: very high throughput, reduced floor space requirement, improved rate of extraction, low and steady power consumption, and very low labour requirement. The chief disadvantage is the overriding need for the centrifugation of part or the whole of the crude oil. Moreover, the wear of the continuous press is relatively severe; efforts are being made, in collaboration with the fabricator to improve its wear resistance.

At the beginning of the research work, there were no mills equipped with continuous presses. At present, several large capacity machines of this type have been or are being installed. It is anticipated that, in the near future, the processing capacity in the mills of cooperative members will approximate 150 t of FFB per hour corresponding to the production by this process of about 30 t of clarified oil per hour.

Clarification of Crude Oil

The technique of clarifying crude oil, omitting the intermediate settling step was developed. The process is likely to have a bright future. It makes it possible to produce oil of first class quality and can be completely automatic.

A sand cyclone for crude oil or for sludge ex-settling tank was developed. It enables the almost complete removal of sand from the liquid phase without significant loss of oil. It was absolutely necessary to develop the cyclone in order to reduce the wear of the sludge centrifuges. Several sand cyclones are already in use or are being installed in a number of mills.

The screening of crude oil is usually performed with screen vibrating in the vertical plane. It was also carried out with screens vibrating horizontally. The advantages of the latter are lower cost and reduced floor space requirement. The efficiency of these screens is quite comparable to that of the conventional types.

It was found possible to increase the capacity of the drier considerably by the dispersion of the oil to an electrically driven disc. It was also possible to prove that the rehydration of oil is practically nil in industrial practice and that, in any event, it is negligible during the time elapsing between production and reception at Leopoldville. Rehydration of oil thus results necessarily from accidental ingress of water.

Quality of Oil

The mechanism of the post-extraction increase in acidity which had been already investigated in 1951, was completely elucidated whilst measures capable of preventing hydrolysis or slowing it down were evolved.

Drying by forced air draught is the most efficient technique for industrial application, the practical advantage of dehydration was already highlighted in recent years. In 1955, the increase amounted only to 0.16%. More than 80 000 t produced by members of the cooperative are now dried at the production centre.

Extremely fast acidification of a type different from the spontaneous autocatalytic hydrolysis has been observed. It has been established that the reaction was of biochemical origin. A highly lipolytic microorganism (Candidum Geotrichiun

Link) is responsible for it. The organism reproduces itself in oil laden with nutrients (impurities and moisture).

This form of hydrolysis can be stopped by sterilisation or filtration of the oil. The oxidation of oil was studied. Under present conditions, the degree of oxidation does not appear as an industrial criterion of the quality of oil provided it does not exceed certain limits which are actually hardly ever reached in practice. The market may however become more selective in future and it will be possible then to lower the peroxide value of oil by chemical deperoxidation (use of reducing agents).

Processing of Nuts

The conditions of nut processing were studied. Information was made available as a result on the most suitable layout to be adopted for a standard kernel plant. The importance of sterilisation was clearly established. An adequate treatment of the bunches permits to do away with the autoclaving and/or the drying of nuts prior to cracking.

The cracking of *tenera* nuts was studied in detail. Crackers of special design (vertical shaft, increased distance between rotor and cracking ring) lead to higher efficiency. The so called 'nut orientation' cracker has been selected by a number of mills dealing mostly with *tenera* material.

The first hydrocyclone made for the separation of the cracked mixture was developed at the instigation and with the collaboration of CCCI at Staatsmijnen. It was installed at Mongana where its advantages were demonstrated. The pneumatic cleaning of the cracked mixture was incorporated in the equipment. It is of great practical interest, particularly in the case of the processing of *tenera* materials.

Finally, a kernel plant of new conception, without grading of either the nuts of the cracked mixture was constructed. The plant consists of four hydrocyclones separating the kernel, shell and the uncracked nut. Equipped with an orientation cracker and a pneumatic cleaner, the plant operates at a capacity in excess of 3 t of nuts per hour with an efficiency of more than 98%.

Utilisation of the Stalks

Owing to their morphology, the stalks constitute a low heat fuel burning with poor efficiency. The different techniques were used to improve combustion efficiency: the shredding/drying process and the gasification process. The first of these makes it possible to use slices of stalk on the grate of furnaces designed for fibre and shell. Gasification requires a special pre-combustion chamber but permits continuous burning of the stalks. Fitted with induced draught this type of furnace has given excellent rates of evaporation. The use of stalks will probably become a necessity when factories process *tenera* crop exclusively in continuous presses. Owing to the composition of the *tenera* fruits, the amount of shell available as fuel is hardly half of that recoverable from an equivalent tonnage of *dura* fruit. Moreover, in the continuous press extraction process, one-third of the fibre is lost into the crude oil. To illustrate the seriousness of the problem, mention is made of the fact that the processing of 1 t of bunches by the continuous press process requires approximately one million calories. These may be provided in equal proportions by the stalks, fibres and the shells, the total number of calories available therefrom being of the order of 11 000 000 calories.

APPENDICIES

APPENDIX 1

Elimination of Sand

The wear caused by sand to oil mill equipment is extensive. Damage is particularly serious in mills dealing with fresh fruit bunches (FFB) which contain relatively more sand than detached fruits. The same remark applies to detached fruits delivered together with bunches (by estates or smallholders) which may contain several percentage units of sand (as much as 20% sand was recorded in some deliveries). The wear caused by sand, that is abrasion, is particularly noticeable in fruit screw conveyors, digesters, presses and sludge centrifuges. The following gives an idea of the extent of abrasion: in a specific instance (Titan semi-continuous centrifuge) the loss of metal (stainless steel) was recorded to be 0.1 μm hr^{-1}.

Although fibre and cellular debris have been proved to be capable of wearing metal (wear of cyclones, ducts and depericarper fans), sand is chiefly responsible for the various cases of abrasion recorded.

A study has therefore been made of the de-sanding of:

- fresh and sterilised bunches and fruits; and
- crude oil.

Removal of Sand from FFB

The sand contaminating FFB cannot be completely removed by water sprayed over a heap of bunches. Even when powerful water hoses are used, de-sanding is far from perfect except for the top layer of bunches directly subjected to the mechanical effect of the water-spray.

Removal of Sand from Fresh Detached Fruit

Pneumatically. The pneumatic separation of impurities made up of sand, calyx leaves and fibrous strands can be easily achieved. Sand is almost completely eliminated by a stream of air of approximately 10 m s^{-1} velocity. Only sand attached to wet bruises of the fruit cannot be separated pneumatically (a portion of the fruit is blown away when the air velocity reaches 16 m s^{-1}).

Hydrocyclone. The results are excellent. Specially prepared mixes of 50 parts of fruit were experimented upon. The separation of the heavy constituent is achieved quantitatively. The treatment is however fairly rough and a large number of fruits are bruised as a result of friction in the ducts and pumps. It could be envisaged to line the surfaces in contact with the fruits with rubber or plastic material. The loss of oil is practically nil.

Screening and water spraying. Screening was carried out through a screen vibrating horizontally. The treatment does not bruise the fruit and, if a thin layer is maintained on the screen, leads to very effective sand removal. Water spraying is useful in eliminating sand stuck to the fruit. In this technique, it must be ensured that no more than a mono-layer of fruits is maintained on the screen. The treatment does not however eliminate calyx leaves, leaflets, *etc*. which show a tendency to accumulate at the fruit outlet.

Sand Removal from Sterilised Fruit

The three procedures described in preceding paragraphs were used on sterilised fruits coming out of the thresher.

The pneumatic separation removes the calyx leaves of the fruit. This was in fact,

the object of the experiments. The clogging of the equipment is very fast and de-sanding is far from being completed (vide separation of impurities in *Appendix* 2).

Through its intense mechanical effect, the hydrocyclone bruises fruits extensively and induces a loss of oil but all the sand is removed as in the case of the fresh fruit.

Screening combined with water spraying gave fairly encouraging result at Mongana. The technique is under test at industrial scale in Bosondjo.

The spray water collected in the small scale trials (1 t of fruit) contained very little oil. Parthenocarpic fruits however go through the screen perforations (14 mm holes) and are lost in the wash water.

Finally, at laboratory scale, sand was removed from a few kilogrammes of fruit by soaking in water at 95°C stirred gently to induce superficial washing. The technique enables complete separation of sand, inclusive of that embedded in the deep bruises of the fruit. Solutions containing a surfactant (0.1% AAS) were also used in the washing process.

Table 1 gives the silica content (SiO_2) of the pulp derived from a sample of sterilised fruit (after the thresher) separated into the following fractions:

- un-bruised fruits;
- bruised fruits; and
- impurities.

The removal of sand from sterilised fruit as it comes out of the stripper is therefore a distinct possibility. It is possible to visualise an apparatus for fruit immersion fitted with forced circulation of water with subsequent separation of the fruit and the sand either statically or by hydrocyclone. Water and a small quantity of oil therein (without sand) can be recycled.

Removal of Sand from Crude Oil

Static de-sanding. In view of the fast rate of settling of sand in crude oil, a step settling table was constructed (*Figure 1a*). It consists of eight steps of dimension 500 x 700 mm. The baffles are mobile to facilitate cleaning (*Figure 1b*). The first trials were made with four steps only and at a throughput of 1500 kg of oil per hour. It was observed that a further few minutes settling of the de-sanded oil led to additional separation of a substance containing a large amount of SiO_2. At the throughput mentioned above, the first three steps fill up with sand visible to the naked eye. In the steps four and eight, the presence of sand can be felt between the fingers.

The apparatus has made it possible to remove approximately 100 g of silica per tonne of crude oil from a continuous press (100% dilution). The de-sanded crude oil contains SiO_2 in the same amount as is normally found in cellular debris, in other words the free sand has been completely eliminated. The drawbacks of the apparatus are: very low hourly throughput, difficulty

TABLE 1. SILICA CONTENT (SiO_2) OF THE CONSTITUENTS OF THE STERILISED FRUIT

	Control unwashed	Fruit washed with water	Fruit washed with water containing 0.1% of AAS
Un-bruised fruit	0.49	0.24	0.15
Bruised fruit	1.49	0.25	0.18
Impurities	1.67	0.25	0.11

Note: Fibre after through oil extraction and washing contained 0.23% of SiO_2

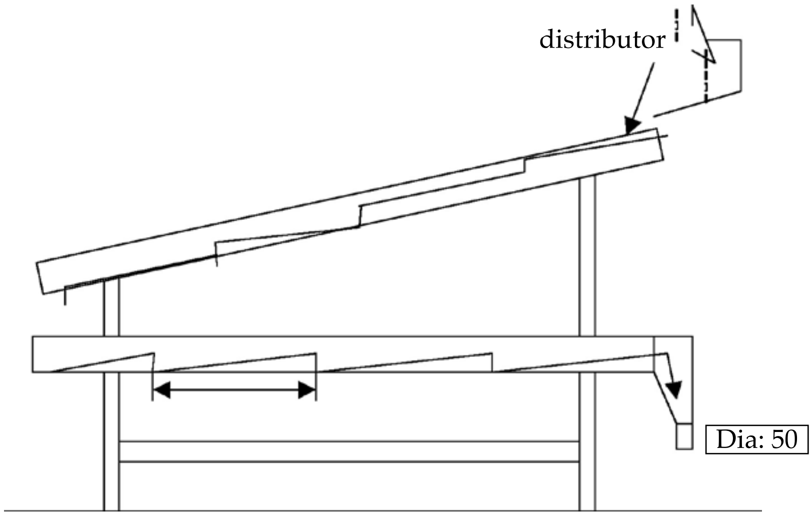

Figure 1a. Step desanding installation – width 70 mm capacity 2 t hr^{-1}.

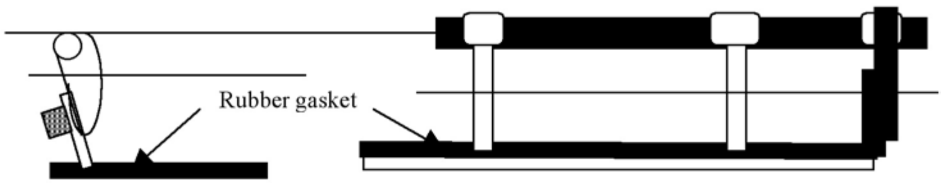

Figure 1b. Detail of removable baffles.

in cleaning it in spite of the removable baffles (oil must first be flushed by displacement with water) and finally the difficulty in levelling it. In contracts, it is a very simple design and does not cost very much.

Sand removal by hydrocyclone. In view of the efficient separation of sand achieved through the use of a hydrocyclone, the technique was applied to crude oil. A cyclone with adjustable or interchangeable elements (height of the cylindrical part, diameter of the underflow outlet, height of the overflow tube, crude oil inlet, de-sanded oil outlet) has enabled cyclones of various capacities to be constructed. They were tested with crude oil to which were added very large amounts of sand (100 kg of earth for instance per tonne of crude oil). Sand removal is very effective. The treated crude oil is found to contain only 0.04% of S_iO_2 originating almost exclusively from the intracellular silica of the impurities of oil. Under favourable operating conditions, the loss of oil in the underflow (containing sand) is 0.02% of the total oil when dealing with sludge and 0.05% to 0.08% when dealing with crude oil, sand cyclones of 12 t hr^{-1} capacity must operate under a pressure of 1.5 kg cm^{-2} to 2 kg cm^{-2} at the inlet. In the case of large cyclones (up to 50 m^3 hr^{-1}), the pressure should range from 1.0 kg cm^{-2} to 1.5 kg cm^{-2}. The feed must match the rated throughput closely. If it is below that level, the sand cyclone does not operate properly. The liquid is entirely evacuated through the underflow entailing heavy losses of oil. The temperature of the materials fed into the cyclone must be approximately 95°C. The oil content of crude oil fed into the cyclone should not exceed 30%. Beyond that limit the efficiency of the apparatus drops considerably. It is therefore impossible to use a sand cyclone for the removal of sand from undiluted press of centrifuge crude oil. Dilution is essential. The highest efficiency is obtained with sludge containing only a few percentage units of oil. In our operating conditions, it was found impossible to apply a back pressure on the outlet of the de-sanded liquid without recording higher losses in the underflow.

In principle, it is possible to use water-tight cyclones and higher inlet pressure in order, concurrently, to apply a back pressure either on the overflow or on the underflow. Such cyclones are commercially available (Krebs, USA).

In the cyclone outlined in *Figure 2*, the top part can be observed to be of relatively large diameter compared with the lower housing. The aim is to lower the back pressure inside the cyclone. (The diameter of the overflow outlet is 75 mm.)

Several sand cyclones described are still in service in oil mills. It has been observed that the feed pumps and cyclones were subjected to very intensive abrasion. The lining of some of the cyclone parts with non-abrasive material and the use of materials with high resistance to abrasion are being investigated.

For information, it is mentioned that Professor Lievens of the Institute of Agronomique, Louvain, agreed to undertake comparative granulometric analyses of the sand added to crude oil and that removed by the sand cyclones. *Table 2* gives the results of the granulometric analysis of sand before and after passage through the cyclone.

TABLE 2. GRANULOMETRIC ANALYSIS

Size (μm)	Sand added	Sand removed
50 – 100	19.9	32.0
100 – 200	30.4	22.9
200 – 500	26.7	17.4
500 – 1 000	11.2	14.8
1 000 – 2 000	0.5	1.0
	88.7	88.1

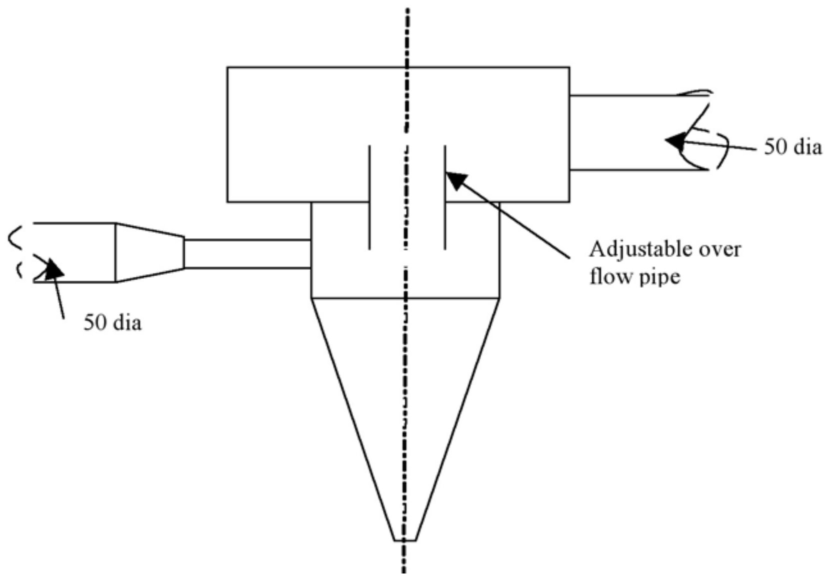

Figure 2. Sand cyclone capacity 12.5 t hr^{-1}.

Professor Lievens drew our attention to the fact that in most Congolese soils there is no fraction of dimension 2 μm to 50 μm. In other words, all particles going through a mesh with 50 μm perforations are in fact smaller than 2 μm. It appears to us that in view of their low kinetic energy, grains of that dimension may be considered as having no abrasive effect. Taking into account the relatively poor accuracy of the granulometric analysis, Professor Lievens feels that the sand is identical in both fractions, at most, that the highest 50 μm to 100 μm fractions recorded in the removed sand may be due to a sort of grinding effect in the pump.

Summing up, the removal of sand is a necessity in mills dealing with bunches and using powerful means of oil extraction and sludge separation (continuous press and centrifugal separation). Sand should be removed from the fruit as early as possible in the processing cycle. Fresh loose fruit supplied by farmers can be cleaned out by screening. That precaution already eliminates a large part of the sand entering the mill. Another part of the sand can be eliminated by screening of the sterilised fruit coming out from the stripper. Finally, the crude oil should be de-sanded in a sand cyclone before being dealt with in a centrifuge. As a sand cyclone cannot cope with undiluted crude oil, it is necessary either to dilute it or, better still, remove a large proportion of the oil by static separation. Only the sludge is then fed into the sand cyclone.

APPENDIX 2

Separation of the Impurities of the Fruit

As mentioned in *Appendix 1* that calyx leaves of the sterilised fruit could be eliminated pneumatically. It is known, on the other hand, that calyx leaves retain a certain amount of oil which does not bleach easily owing to fast degradation through exposure to air. Additionally, some impurities of the fruit contain chlorophyll, part of which migrates into the oil in the digestion stage of the process and is responsible for the green tinge found in the bleached oil.

It was therefore logical to eliminate all impurities of the fruit by a pneumatic process.

The impurities of the sterilised fruit emerging from the stripper (fruit derived from FFB) consist of the following:

- calyx leaver (70%);
- parthenocarpic fruits (20% approximately); and
- true impurities (sand, leaves, strands of vegetable matter, miscellaneous debris).

The impurities represent approximately 10% of the weight of the sterilised fruit. Calyx leaves which are the main constituent contain approximately 25% of oil (and wax) on wet basis, that is 40% on dry matter. The overall oil content of the impurities is therefore not negligible and it would be inadvisable not to envisage its recovery when the impurities, are separated from the fruit.

The impurities were consequently subjected to centrifugation or were pressed following heating and digestion. It was possible to recover 12% and 20% of oil on wet basis respectively. This represents 3% and 6% of the total oil of the bunch.

The oil extracted from calyx leaves is always unbleachable (out of the Lovibond range). This is probably due to the oxidation of oil in the course of the various treatments. The oil extracted from parthenocarpic fruits shows generally about 10 units of red and up to 10 units of blue in the Lovibond apparatus.

The oil is therefore distinctly green since readings of 0.2 to 0.3 units of blue in bleached oil already impart of pale greenish tinge to the oil. Oil extracted in the laboratory from the true impurities has a high chlorophyll content.

Using an air stream velocity of 6 m s^{-1}, it is quite possible to separate pneumatically the calyx leaves and true impurities but the separation of parthenocarpic fruits is incomplete. The apparatus gets clogged up fast.

The separation of the calyx leaves and parthenocarpic fruits can be achieved easily in a rotating drum fitted with a 9 mm x 60 mm perforated screen. Unfortunately, the impurities such as leaves which affect bleaching adversely are not eliminated by the process.

Briefly, if oil with 1.0 to 1.2 units of red is to be produced, the separation of impurities is not required. If it were deemed advisable at some future date to produce oil with 0.6 unit of red, the minimum that can be achieved industrially, it would be necessary to separate the impurities. This implies of course the separate recovery of the oil present in them (3% to 6% of the oil).

It is pointed out that currently oil is considered as having satisfactory bleaching characteristics if it does not have more than 2.0 units of red on leaving Congo ports and if it exhibits a normal stability of storage.