Feature Article

Benefits of Using Fourier-Transform Near Infrared (FT-NIR) Spectroscopy for the Palm Oil Industry

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In the palm oil industry, various methods used for the control of product quality are of interest. The palm kernels sold to the kernel crushing factory should strictly adhere to the sales specifications of kernel mentioned in the sales agreement that stipulates the minimum allowable contamination of dirt and moisture in the kernel consignment. After crushing the kernel to extract the kernel oil, the residue called expeller is analysed for the residual oil and contaminant content. The percentage residual oil content in the expeller will give the extraction efficiency of the kernel extraction plant. The production kernel oil also undergoes analyses as it also has to meet the sales specifications on quality. Similar analysis is also conducted by the kernel oil refinery when it receives the kernel oil from the kernel crushers. Currently, all the important tests to monitor product quality in the palm oil mills, refineries, kernel crushing plants and kernel oil refineries are carried out using lengthy procedures. This can be a set-back for timely quality control of the products as the time lag could cause the production of off-quality products for long periods. Until recently there were no instruments that could analyse the quality parameters that are critical in a continuous production line.

Today, high technology analysers can deliver fast results and be easily interfaced with computers. One of them is the Near Infrared (NIR) spectroscopy, a popular method used extensively for many year by the farming community especially in the developed nations. The latest offerings by the multi-purpose spectrometers are not only capable of analysing both liquid and solid samples, but are also non-destructive

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that can analyse residual oil levels in the feed material on a continuous basis. Measuring samples could be as easy as putting liquid samples in disposable glass vials (*Figure 1*) or solid samples in Quartz or glass window sample cups. Measurements take less than a minute. Furthermore, a high light thorough-put instrument could even surpass the limitations of lab measurements, with contactless measurement heads, probes or flow cells installed directly inline or online for real-time process monitoring leading to even better quality control. The FT-NIR technology allows separation of more than 100 m between the probes and the spectrometer. In addition to key product parameters, dedicated applications like the storage analysis of various oils or the monitoring of the degradation processes in used frying oils have been explored and even certified. It should be noted that with high resolution FT-NIR technology, oil producers or buyers could analyse multiple components in less than 1 min without any special preparation of chemical substances or user expertise. Moreover, standardisation of instruments across unit, time or model is not required.

ANALYSIS OF PALM KERNELS

NIR analysis of palm kernels plays a major role in ensuring quality in both food and agricultural products, offering assistance to solve the problems of palm oil producers as well as palm breeders. Palm kernels and their intermediate products, like expellers or extracts can be analysed for oil, protein and moisture content, thus optimising the oil pressing process and increasing plant efficiency. *Figure 2* shows examples of moisture and fat predictions in palm kernels.

At each stage of the plant breeding process, the breeder must choose the best kernels for propagation to the next generation. FT-NIR can have a great impact on the agricultural sector especially the plant breeding-sector, since it is capable of measuring many of the important traits.

QUALITY CONTROL OF CRUDE PALM OIL

Crude palm oil (CPO) has been used as raw material in various industries including palm oil refining, oleo chemicals, food and agriculture such as animal feed. The quality of CPO is critical for its sale as well as for process optimisation. Disposable glass vials are filled with molten CPO for FT-NIR measurement as described in *Figure 1*. Quality parameters such as free fatty acid (FFA) or even Deterioration of Bleach Index (DOBI) can be measured precisely.

QUALITY CONTROL OF FINISHED PALM OIL AND DERIVATIVES

One of the most important parameter of oil and fat is the iodine value (IV) as it is a good measure to predict physical appearance as well as the process ability of the fat. IV is defined as the grams of Iodine absorbed by 100 g of fat or oil. The higher the IV, the softer the fat. The analysis of IV by FT-NIR is an official AOCS method (method Cd1e-01). Other quality parameters such as the acidity of the oil can be determined simultaneously with the same measurement. The more fatty acids are freed from the glycerine

backbone, the more acidic the material is. This is expressed as the free fatty acid (FFA) content. Moreover, the health relevant trans fatty acid (TFA) content can be analysed.

Unlike other edible oils, palm oil refining produces various products such as refined bleached and deodorised (RBD), palm olein, palm stearin and palm kernel oil. General/ universal calibration equations to predict compositions/properties including IV, FFA, slip melt point (SMP), moisture and impurity (M&I) or moisture content for all palm oil products could be developed. *Table 1* shows example of those universal calibrations. It must be noted here that the accuracy of calibrations indicated by the value of root means square error of prediction (RMSEP) in the *Table 1* is just an example. The RMSEP could vary significantly based on the method of sampling, accuracy of reference analysis and the range of parameter explored.

For higher accuracy, a dedicated calibration equation for a particular palm oil product can be developed. For example, *Table 2* also shows that the accuracy of dedicated calibration for FFA of RBD is at ±0.017%. This is much better than that of the general palm oil (various products included) at ±0.05%. By using the powerful tool chemometrics, a mathematical method to extract hidden information can be obtained from the FT-NIR spectra, FFA of particular palm oil products mentioned above could be measured at superior accuracy, in general, with an error that is less than ±0.05%.

Another benefit of FT-NIR is that its high reproducibility and accuracy will allow the measurement of fatty acid profiles, which can be used to evaluate oil stability, food functionality and oil authenticity. FT-NIR can be used to precisely analyse the fatty acid profile such as C16:0, C18:0, C18:1, C18:2, *etc*., while simultaneously measuring other general parameters such as IV, FFA, *etc*.

MONITORING OF FRYING OIL QUALITY

In recent years, fried food has been stigmatised due to its suspected negative impact on health associated with cardiovascular disease, obesity or diabetes. The fact, however, is that the quality of the frying fat heavily influences the quality of the finished product. This can be easily debated when we consider that a raw potato having a fat content of 1% can accumulate more than 30% fat from the frying oil after frying. What is needed here is obviously a good and continuous automatic quality control system with a feed back loop. This requires a quick analytical equipment that can analyse the samples as fast as possible so that remedial actions can be enforced in time. While the small frying operators mostly rely on experience and occasional quick test solutions like visual test strips or simple conductivity measurements, it is of utmost importance to constantly monitor the frying medium in large-scale industrial fryers with high turnovers. Any deviation from the guaranteed quality will lead to loss in consumer trust and potential claims. Moreover, tight control of oil quality helps to manage replenishment costs.

Quality parameters like Acid Value (FFA), Anisidine Value and other parameters

which describe the degradation of the frying oil like Total Polar Compounds (TPC) and Di- and Polymeric Triacylglycerols (DPTG), have to be under good control if the quality of the fried product is meet the quality standards. The conventional testing is time consuming and does not allow a timely implementation of an immediate automatic corrective action. Utilising fast FT-NIR spectroscopy will effectively prevent the massive production of off-quality food products!

FT-NIR spectroscopy offers a precise and hassle free solution for this application (*Table* 2). This was acknowledged by the German Society for Fat Science (DGF) who issued the Standard Method 'FT-NIR Spectroscopy: Screening analysis of used frying fats and oils for rapid determination of polar compounds, polymerised triacylglycerols, acid value and Anisidine Value [DGF C-VI 21a (13)]' in September 2013.

Figure 1. Rapid oil analysis with FT-NIR using disposable glass vials.

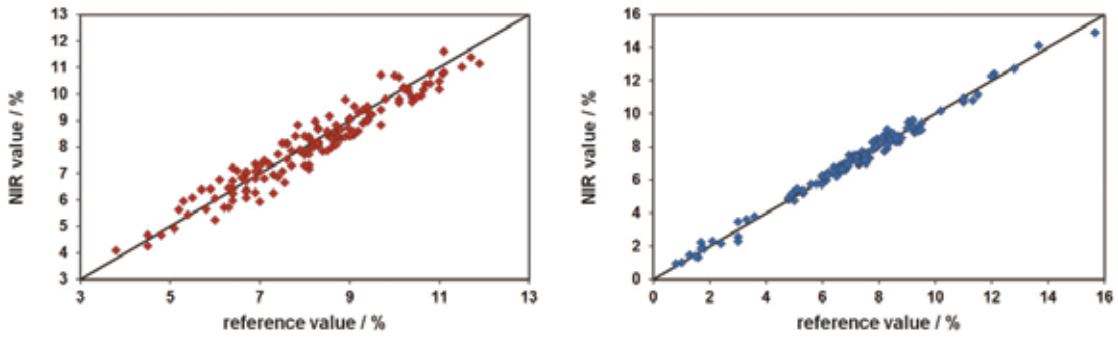

Figure 2. Calibration results of moisture (left) and fat contents (right) in palm kernel.

TABLE 1. VALIDATION RESULTS FOR VARIOUS PARAMETERS OF PALM OIL IN COMPARISON TO VALIDATION RESULTS OF FREE FATTY ACID (FFA) CONTENT IN DEDICATED PALM OIL PRODUCTS

Product	Parameter	Min.	Max.	RMSEP
General palm oil	FFA	0%	13%	0.19%
	FFA (low)	0%	1%	0.05%
	Iodine value	0	65	0.45
	Moisture	0%	0.25%	0.019%
	Slip melt point	12°C	55°C	1.33°C
Refined bleach and deodorised (RBD) palm oil	FFA	0.02%	0.40%	0.017%
Palm olein	FFA	0.03%	1.10%	0.038%
Palm stearin	FFA	0.02%	0.58%	0.017%

Note: RMSEP - Root mean squares error of prediction, indicating error of the measurement.

TABLE 2. VALIDATION RESULTS FOR THE ANALYSIS OF OVER 400 FRYING FAT SAMPLES COLLECTED FROM VARIOUS FAST FOOD RESTAURANTS, BAKERIES, CATERERS AND INDUSTRIAL PRODUCERS

Parameter	Min.	Max.	RMSEP
Acid value (AV)	0.1	5.7	0.18
Anisidine value (AnV)	0.0	172.6	7.88
Di-and Polymeric Triacylglycerols (DPTG)	0.0%	31.3%	0.66%
Total polar compounts (TPC)	2.0%	44.2%	1.63%

Note: RMSEP - Root mean squares error of prediction, indicating error of the measurement.