

# INNOVATION FOR OIL EXTRACTION METHOD USING NMR IN BUNCH ANALYSIS<sup>1</sup>

JUNAIDAH J<sup>1</sup>, KUSHAIRI A<sup>2</sup>, JONES B<sup>3</sup>, KHO L E<sup>4</sup>, ISA Z A<sup>5</sup> AND RUSMIN J<sup>1</sup>

1. Johor State Farmers Organization, No 7 & 8, Jalan Lingkaran, Taman Sri Lambak, 86000, Kluang, Johore
2. Malaysian Palm Oil Board, No 6, Persiaran Institusi, Kajang Selangor
3. Oxford Instruments Magnetic Resonance, Tubney Woods, Abingdon, Oxfordshire OX13 5QX, UK.
4. PLT Scientific Sdn. Bhd., No. 7, Jln BP 4/8, Bandar Bukit Puchong, 47120, Puchong, Selangor, Malaysia.
5. EPA Management Sdn Bhd. P.O. Box 141, 81900 Kota Tinggi, Johor

## ABSTRACT

*The process known as bunch analysis is currently used by oil palm breeders to estimate the oil palm fruits and oil components. From the bunch analysis method of Blaak et al. (1963), the oil is determined using the Soxhlet extraction method. However, an alternative to the solvent extraction method of analysis is needed as n-hexane used as an extraction solvent is a narcotic agent which may affect the operators' safety and health in the long run. Analyzing oil content with a pulsed Nuclear Magnetic Resonance (NMR) analyzer is introduced in this study to provide breeders with an option for oil analysis without any usage of n-hexane. In addition, a reduction of 18% in the work process is noted by switching from Soxhlet extraction to the NMR method. In the verification process, the estimated values for the NMR method are found to be comparable to the values obtained by Blaak's Soxhlet method. The mean oil to dry mesocarp (O/DM) for the Soxhlet and NMR methods were 77.13% and 76.60% respectively with a mean differences of 0.53 and no significance differences from independent sample T-Test analysis. Independent T-Test analysis for oil to wet mesocarp (O/WM) by Blaak's soxhlet and NMR method also indicated no significance differences with a mean difference of 0.35%. As for oil to*

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*bunch from the mesocarp (MO/B), the analysis for independent T-Test for mesocarp oil to bunch (MO/B) also showed no significant difference between the two methods with a mean difference of 0.34%. Apart from its ability in making a direct measure for O/DM, the NMR analyzer is also capable of analyzing the oil to dry kernel which is currently not being captured by Blaak's extraction method. New traits deriving from the NMR method are oil to dry kernel (O/DK), oil to wet kernel (O/WK) and kernel oil to bunch (KO/B).*

## INTRODUCTION

Development for high oil yield planting materials remains the primary objective in most oil palm breeding programmes. The estimation of oil yield production (kg/palm/year) requires information of the oil to bunch ratio (%) and fresh fruit bunch (kg/palm/year). The process known as bunch analysis is currently used by oil palm breeders to estimate the fruits and oil components in the bunch. The procedures and steps mostly follow the bunch analysis method of Blaak *et al.* (1963) modified by Rao *et al.* (1983).

The Blaak method is used by most Malaysian breeders although some authors reported that the oil to bunch figures obtained seldom agree with the oil extraction rates (OER) from palm oil mills (Hor *et al.*, 1996). On the other hand, Lim and Toh (1984) highlighted that Blaak's method tends to overestimate the o/b ratio due to positive systematic errors in the various bunch component ratios. To overcome bias introduced by the loss of moisture in every step of the analytical process, Lim and Toh (1984) introduced a method based on the quantity of oil and kernel produced. The method was further improved by Chan *et al.*, 1999 by eliminating the tedious manual depericarping process. Apart from these, Methews *et al.* (2009) introduced a method of inclusion of parthenocarpic fruits in the bunch analysis procedure to avoid exaggeration of the value of the oil to bunch ratio.

Reviews on the bunch analysis method by Blaak *et al.* (1963) were mostly focussed on the sampling technique for more accurate oil determination. A different approach was taken in this study where the authors kept the sampling procedure and followed most procedures by Blaak *et al.* (1963) modified by Rao *et al.* (1983) but introduced an alternative method of analyzing the oil content. The alternative method introduced was the use of the Nuclear Magnetic Resonance

(NMR) analyzer, following a method developed from routine use of such instruments to measure oil in oilseeds (Oxford Instruments: Measurement of Oil in Seeds application note). By using an NMR analyzer, the utilization of n-Hexane (Chemicals listed under US Toxic Release Inventory (TRI) since 1994 under National Safety Council, 2007) in the Soxhlet extraction method can be avoided.

An alternative to the Soxhlet extraction method in current bunch analysis procedures is needed as n-hexane used as an extraction solvent is a narcotic agent which may affect the operators' safety and health in the long run. Furthermore, the effect of n-hexane exposure in humans has been documented by many authors worldwide. In addition, The neuropathic toxicity of n-hexane in humans is well documented; cases of polyneuropathy have typically occurred in humans chronically exposed to levels of n-hexane ranging from 400 to 600 ppm, with occasional exposures up to 2,500 ppm [Hathaway et al. 1991]. Acute exposure to n-hexane may cause dizziness, confusion, nausea, headache, and irritation of the eyes, nose, throat, and skin [Hathaway *et al.*, 1991]. On the other hand, long-term exposure to n-hexane may cause disturbances in sensation, muscle weakness, and distal symmetric pain in the legs. Clinical changes include muscle atrophy, decreased muscle strength, footdrop, numbness, prickling, and a tingling sensation in the arms and legs. Changes in vision may also be a symptom of chronic exposure to n-hexane [Hathaway *et al.*, 1991].

The introduction of a bench top machine known as an NMR analyzer in this study provides breeders with the option of determining oil and kernel content in oil palm with an n-hexane free method. Nuclear Magnetic Resonance (NMR) was first described and measured in 1938 (Rabi *et al.*, 1938). It has been used in a wide range of scientific disciplines from spectroscopic analysis to medical imaging. In industrial quantitative analysis it is mainly used to measure the concentration of oils and fats in a wide range of industrial products (*Table 1*).

**TABLE 1: INDUSTRIAL APPLICATIONS FOR BENCH TOP NMR**

Applications Area	Applications Include
Food and Agriculture	Oil and moisture in seeds/grain Fat in chocolate Oil content in snack food/dried foods Fat content in infant nutritional formula/animal feed Solid fat content (SFC) in edible oils and fats
Textile / Polymers	Spin finish on fibre Oil, lotion and finish oils on various finished textiles
Research	Rock core analysis Diffusion/hydration studies Freezing and thawing studies
Petrochemicals	Hydrogen in fuels Rubber in PMMA Oil in Sulphur Plasticiser in PVC Oil in wax
Pharmaceutical / Healthcare Other	Fluorine in toothpaste Moisture in tablets Fluorine in alumina and fluorspar Calcium fluoride content of calcium sulphate

The bench top NMR analyser offers several important advantages over other laboratory analytical techniques on oil and fats measurement (MQC brochure, 2010). The most useful benefit is that the measurement is non-destructive, which means that there is no damage to the sample in any way, so the samples can be kept if necessary for repeat measurements. Also the method does not require any usage of solvent or other chemicals, thus removing the need for fume cabinets and expensive disposal procedures. This has direct benefits for several areas of industry where current tendencies and legislation require a reduction in the use of hazardous or environmentally unsafe chemicals and solvents. On the other hand, sample preparation is minimized with samples simply being loaded into tubes, weighed, then

measured directly after a short period of temperature equilibration. NMR measurements are generally insensitive to colour, particle size and other physical properties of the samples. As a consequence, calibrations tend to be easy to carry out, requiring only a handful of samples. Once established, calibrations are robust and need to be repeated infrequently. Once the calibration has been generated, measurements of samples takes typically from a few seconds to a few minutes only. The short measurement time allows a high throughput of samples and efficient laboratory operation. Due to the fact that the NMR signals are generated from all parts of the samples and not just from the surface, the NMR method guarantees accurate measurements. This paper will also describe the detailed method together with its oil analysis results and performance as compared to the current method.

## MATERIALS AND METHODS

A total of 252 bunches (141 *duras* and 111 *teneras*) were sampled and evaluated in this study. Each sample is monitored started from its harvested ripe bunches until its complete process of bunch analysis by the method of Blaak *et al.*, (1963) modified by Rao *et al.*, (1983) and described by *Kushairi* (2005).

At the bunch analysis laboratory, each bunch is weighed and chopped on a wooden table surrounded on three sides. After all spikelets are removed from the stalk, the spikelets are thoroughly mixed on the table with a shovel. The spikelets are randomly sampled for fruit to bunch (F/B) and fruit components (FC) analysis by pulling the spikelets and letting them fall into collecting boxes. The F/B weight ratio is determined after the weights of empty spikelets as well as fertile and parthenocarpic fruits are recorded. However, before the weights are recorded, the spikelets of F/B samples are retted for two days to facilitate manual picking of the fruits from the spikelets.

While the fruit sample for the F/B component is being retted, fruit components analysis continues immediately following the spikelet sampling. Fruit separation from the fresh spikelets is done with a sharp knife. Following the fruit separation, a sub sample of fruits

is taken for fruit component and determination. Sub sampling of fruits is done using a random-box. The sampled fruits, weighing about 300gm and consisting of about 30 to 40 fruits, are depericarped using a sharp knife. The pericarp or mesocarp is dried in an oven at 195°C for 24 hours and weighed as soon as possible. The oven-dried mesocarp is then ground, normally with a food blender and a fresh sample of mesocarp is taken. The ground mesocarp is sieved, using a 0.32 cm (0.125 inch) mesh.

The minced mesocarp was then used to prepare two sets of 5 gram samples for oil analysis, first by Blaak's Soxhlet extraction using a Soxhlet extractor and heating mantle and secondly by the NMR method using a pulsed NMR analyzer model MQC-23 from Oxford Instruments UK. In the Blaak's extraction method, the 5gm samples are placed in stapled filter-paper sachets and stacked in the extraction column of the Soxhlet extractor with 500-5000 ml capacity. The sample then undergoes oil extraction for 16 to 19 hours using n-hexane as the direct solvent. The percentage of oil in the dry mesocarp is computed from the weight of the mesocarp before and after extraction.

Unlike in the Soxhlet method, the minced mesocarp of the second sample can be measured straight away for the percentage of oil to dry mesocarp (O/DM) in the NMR analyzer, after placing about 5 grams of the sample in a 26mm sample tube sealed by parafilm or a teflon stopper and allowing 30 minutes of temperature equilibration in a heating block. All the measurements are obtained using a calibration curve generated from NMR measurements of crude palm oil as 100% oil and an empty tube as 0% oil as shown in *Figure 1*. On the other hand, the determination for the oil to dry kernel is done by placing dry fruit kernels in the sample tube without any blending process. The schematic diagrams for complete bunch analysis processes with the Soxhlet and NMR methods are shown in *Figure 2* and *Figure 3*. The differences in the oil determination steps and procedures are summarized in *Table 2*.

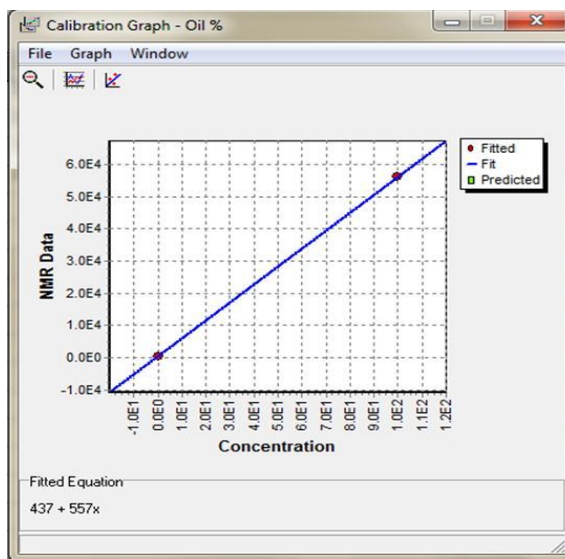


Figure 1 : 100% oil calibration. The screenshot from EasyCal RI Calibration software of MQC-23, Oxford Instruments.

TABLE 2: PROCEDURE FOR OIL ANALYSIS WITH BLAAK'S SOXHLET METHOD vs NMR METHOD

No	Process	Method	
		Soxhlet	NMR
1	Prepare extraction thimble measuring 7.5 x 15 cm	Yes	No
2	Weigh 5 g mesocarp	Yes	Yes
3	Put mesocarp sample into extraction thimble, pack and staple (soxhlet method) or 26mm tube (nmr method)	Yes	Yes
4	Put mesocarp sample (in extraction thimble) into oven (40° C) for two hours	Yes	No
6	Extract oil using Soxhlet extractor with solvent (n-haxene)	Yes	No
7	Extract for 18 – 24 hours (until the solvent turns into its original colour)	Yes	No
8	Measure (O/DM) with NMR equipment	No	Yes
9	Remove sample from soxhlet extractor	Yes	No
10	Dry it in oven (105°C) for 2 hours	Yes	No
11	Weigh fibre & extraction thimble	Yes	No
12	Data Compilation and O/DM derivation	Yes	No

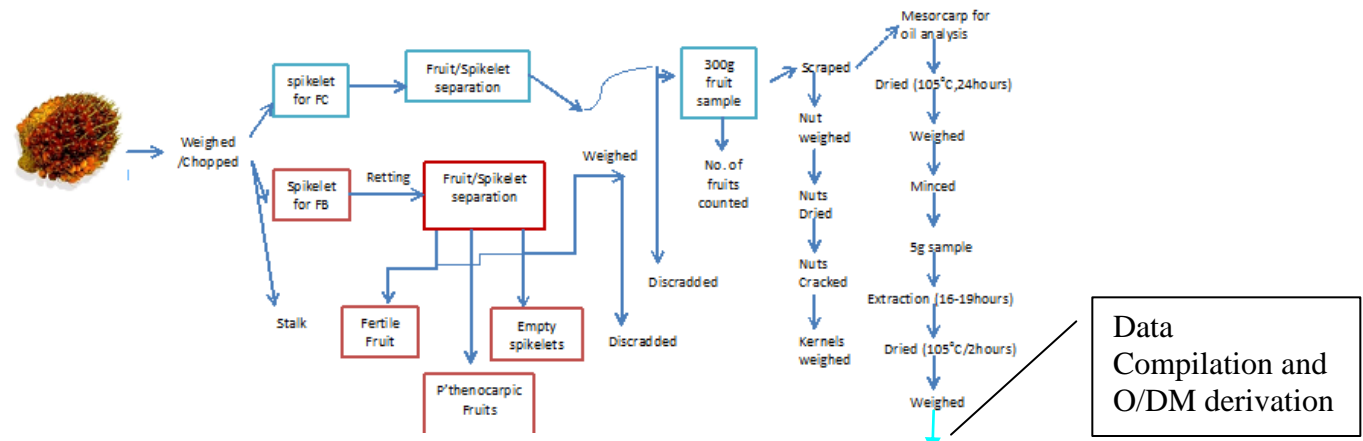


Figure 2 : Bunch Analysis Procedure for Oil to bunch determination in oil Palm with Blaak's Soxhlet Method

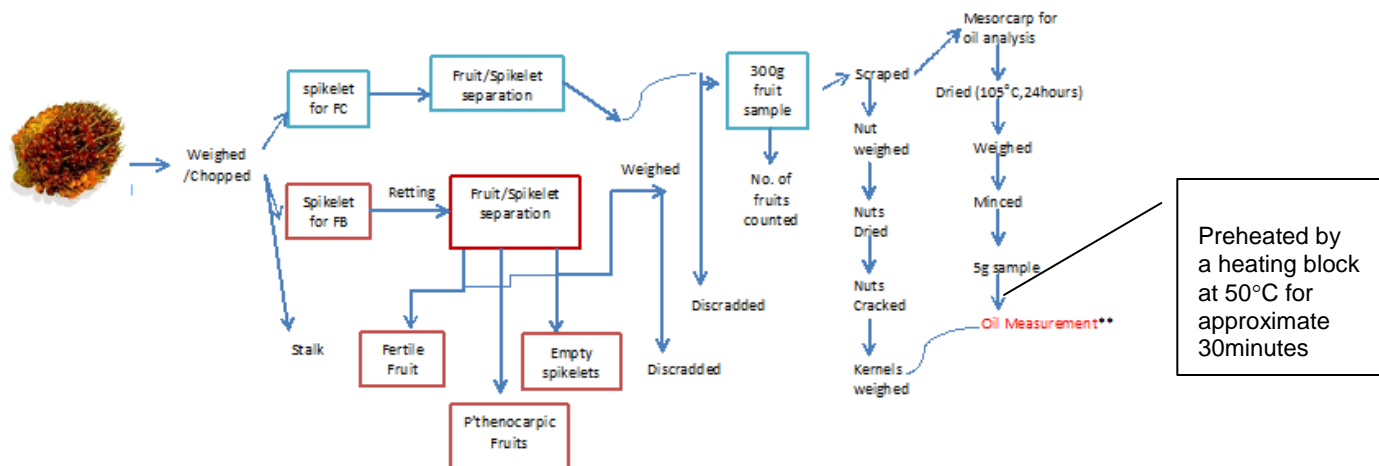


Figure 3 : Bunch Analysis Procedure for Oil to bunch determination in oil Palm with NMR Method



## RESULTS AND DISCUSSION

### Comparison between Means

The accuracy of the NMR method was verified by comparing the estimated mean values derived from NMR samples against the estimated values obtained by Blaak's Soxhlet method. Except for percentage fruit to bunch (F/B), other components of mesocarp oil to bunch component (MO/B) were evaluated and compared.

Results for the oil to dry mesocarp (O/DM), oil to wet mesocarp (O/WM) and MO/B for both NMR and Blaak's Soxhlet method are summarized in *Table 3*. The mean value of O/DM for Soxhlet and NMR methods was 77.13% and 76.60% respectively with mean differences of 0.53%. The slim differences recorded resulted in no significance differences for O/DM derived from the Soxhlet method and from the NMR method from Independent sample T-Test analysis. It is also noted that the NMR method recorded a smaller coefficient of variation (CV) for O/DM compared to Blaak's method.

As for oil to wet mesocarp (O/WM), the Independent T-Test analysis also indicated no significance differences between Soxhlet and the NMR method (*Table 3*). The mean difference between the methods was 0.35% with Soxhlet recording slightly higher mean values when compared with the NMR method. However the CV for O/WM derived from the NMR method is slightly lower than the CV of the Soxhlet method.

The analysis for independent T-Test for mesocarp oil to bunch (MO/B) also showed no significant difference between the methods (*Table 3*). The percentage of mesocarp oil to bunch (MO/B) produced by the Soxhlet method (MO/B) is 0.34% higher than from the NMR method. It was also noted that although the coefficient of variation for O/DM and O/WM are less than 15%, the CV for MO/B was higher (> 20%). This is due to the influence of F/B components, another component required in the derivative of MO/B.

As the NMR method provides options in measuring the O/DM either from the ground or scraped mesocarp, results for both measurements are also presented in *Table 3*. Significant results were noted from the independent T-Test tested on O/DM estimated from scraped and ground mesocarp. Scraped mesocarp recorded a 1.77% higher O/DM when compared to ground mesocarp. Less O/DM is expected in ground mesocarp due to losses incurred during the grinding process with a food blender.

**TABLE 3 : COMPARISON OF BUNCH COMPONENTS MEANS FOR OIL DETERMINATION WITH SOXHLET AND NMR METHOD**

No.	Traits	Method	n	Range	Mean	CV%	Mean Different	t-test (p-value)
1	O/DM (%)	Blaak's Soxhlet	252	34.65	77.136	5.21	0.53	0.124ns
		NMR	252	31.57	76.607	4.81		
2	O/WM (%)	Blaak's Soxhlet	252	54.23	49.67	13.37	0.35	0.549ns
		NMR	252	52.93	49.32	13.15		
3	MO/B (%)	Blaak's Soxhlet	252	31.78	23.38	21.94	0.34	0.446ns
		NMR	252	30.93	23.04	21.47		
4	O/DM (%)	NMR_Grind	252	31.57	76.61	4.81	1.77	0.000 ***
		NMR_Scrape	252	31.61	78.38	5.50		

\*\*\* significant at 0.05% level

n = Number of bunch  
 CV (%) = Coefficient of Variation  
 O/DM (%) = Oil to Dry Mesocarp  
 O/WM (%) = Oil to Wet Mesocarp  
 MO/B (%) = Mesocarp Oil to Bunch

## Correlation Analysis

The correlation and their relationship analysed with respect to the oil component derived from the Soxhlet and NMR methods is shown in *Table 4* and *Figure 4* to *Figure 6* respectively. The accuracy and similarity result from both methods are shown by the highly significant correlation coefficient value (*Table 4*). The Pearson correlation (r) figures of more than 0.95% indicated a strong positive linear relationship between Blaak's Soxhlet and the NMR method for oil components. The value of correlation coefficient for oil to dry mesocarp (O/DM) between Soxhlet (O/DM) and NMR method (O/DM) is highly significant with the R value of 0.956. This indicated the existence of strong positive relationships between soxhlet O/DM and NMR O/DM. Similar result was noted for oil to wet mesocarp (O/WM) and mesocarp oil to bunch (MO/B) between Soxhlet and NMR method with a strong positive of R = 0.994 and R = 0.991 respectively. The graphical relationship between both methods for each trait is shown in figure 4 to figure 6.

**TABLE 4 : CORRELATION ANALYSIS BETWEEN SOXHLET AND NMR METHODS**

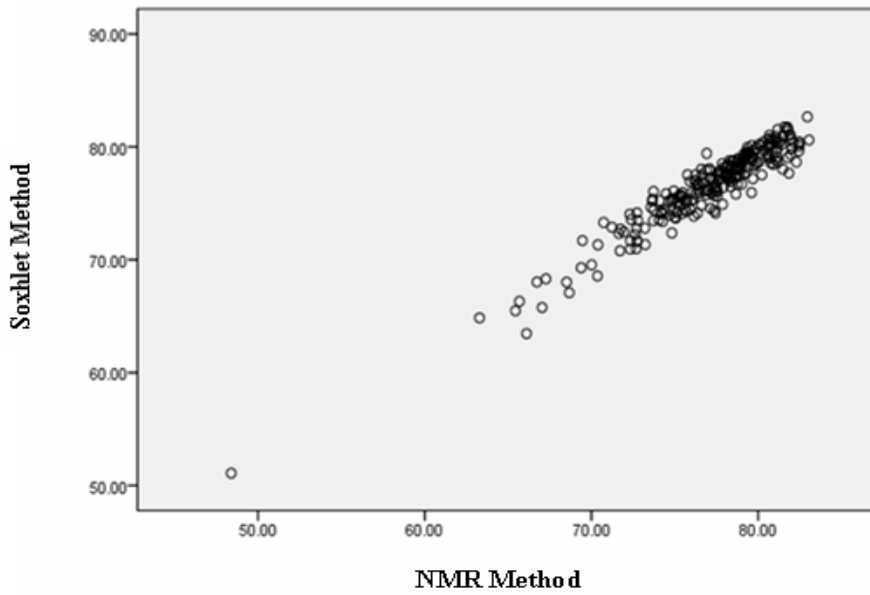
No.	Traits	Method	Correlation Coefficient ( <i>p-value</i> )	Pearson Correlation (r)
2	O/DM	Soxhlet (O/DM) NMR (O/DM)	0.000***	0.956
3	O/WM	Soxhlet (O/WM <sub>1</sub> ) NMR (O/WM <sub>2</sub> )	0.000***	0.994
4	MO/B	Soxhlet (MO/B <sub>1</sub> ) NMR (MO/B <sub>2</sub> )	0.000***	0.991

\*\*\* = Significant at 0.05% level

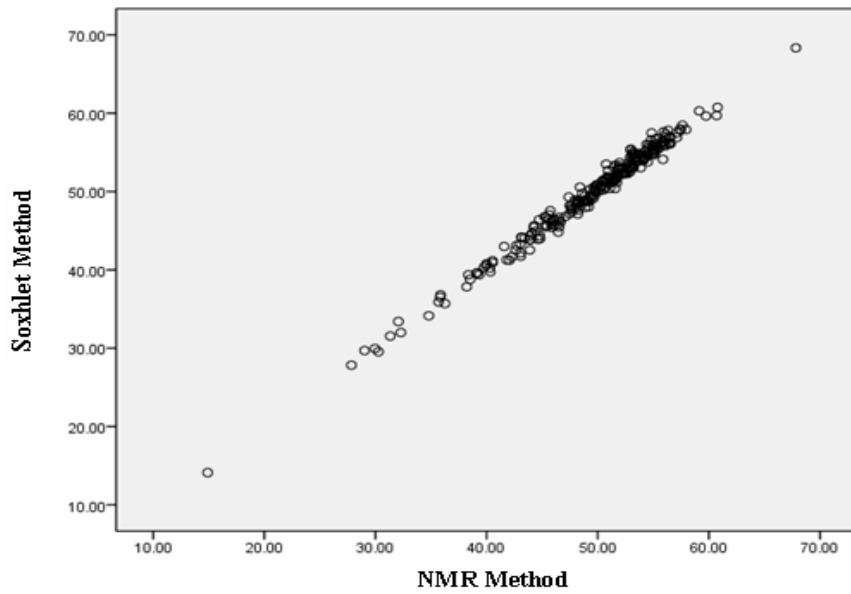
O/DM (%) = Oil to dry mesocarp

O/WM (%) = Oil to wet mesocarp

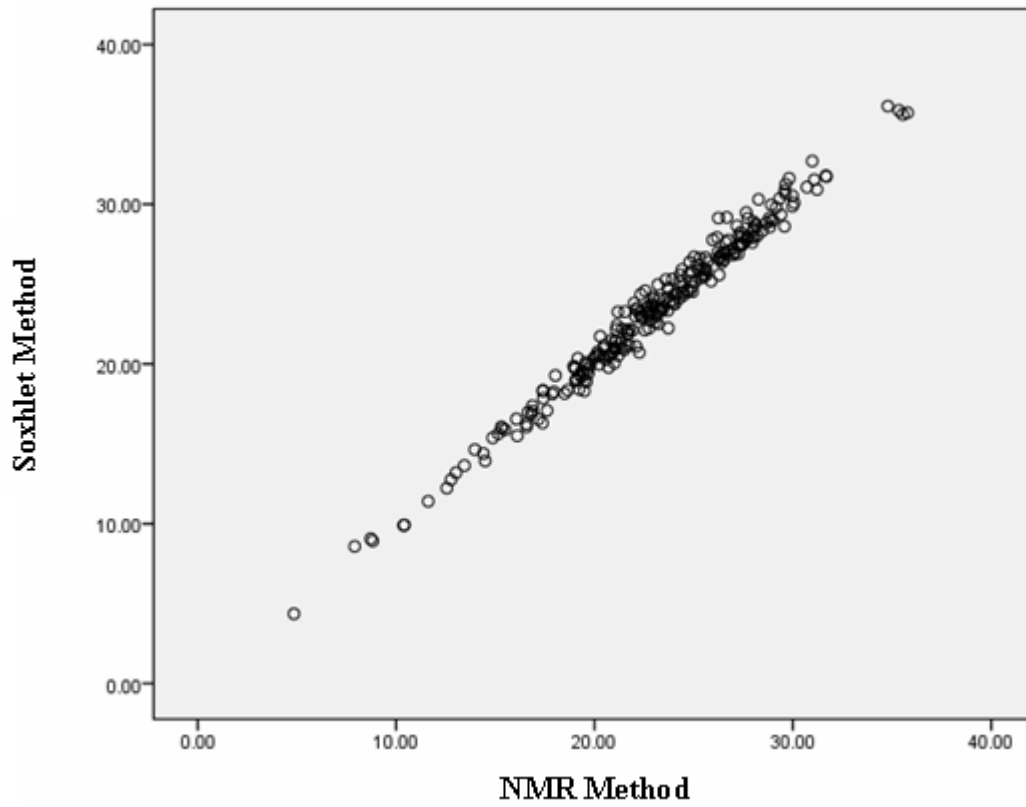
MO/B (%) = Mesocarp oil to bunch



**Figure 4 : Relationship between Soxhlet Method VS NMR Method for Oil to Dry Mesocarp (O/DM)**



**Figure 5: Relationship between Soxhlet Method vs NMR Method for Oil to Wet Mesocarp (O/WM)**



*Figure 6: Relationship between Soxhlet Method VS NMR Method for Mesocarp Oil to Bunch (MO/B)*

## Derivatives Formulae

The complete computational formulae for all bunch analysis traits are summarized in *Table 5*. Formulae remain similar except for the oil analysis components due to the straight measurement of percentage of oil to dry mesocarp (O/DM) and oil to dry kernel (O/DK) by the NMR method. By having direct measurement with NMR, the fibre component measurement required for the derived O/DM formulae in soxhlet method has been skipped. The samples of data for O/DM (%), O/WM (%), MO/B(%) and O/F (%) derived from both Soxhlet and NMR methods are summarized in *Table 6*. In addition traits related to kernel oil are presented in *Table 7*.

**TABLE 5 : COMPUTATION FORMULAE FOR BUNCH COMPONENTS (Soxhlet & NMR)**

No.	Traits	Abbr.	Soxhlet Method	NMR Method
1	Fruit/ Bunch (%)	F/B	$((FFWT+PFWT)/SWT) \times ((BWT-STKWT)/BWT) \times 100$	$((FFWT+PFWT)/SWT) \times ((BWT-STKWT)/BWT) \times 100$
2	Fertile Fruit /Bunch (%)	FF/B	$(FFWT/SWT) \times ((BWT-STKWT)/BWT) \times 100$	$(FFWT/SWT) \times ((BWT-STKWT)/BWT) \times 100$
3	Parthenocarpic/Bunch (%)	P/B	$(PFWT/SWT) \times ((BWT-STKWT)/BWT) \times 100$	$(PFWT/SWT) \times ((BWT-STKWT)/BWT) \times 100$
4	Mean Fruit Weight (g)	MFW	FSWT/NOFNUT	FSWT/NOFNUT
5	Mean Nut Weight (g)	MNW	FNWT/NOFNUT	FNWT/NOFNUT
6	Mesocarp/Fruit (%)	M/F	$((FSWT-FNWT)/FSWT) \times 100$	$((FSWT-FNWT)/FSWT) \times 100$
7	Kernel/Fruit (%)	K/F	$(KWT/FSWT) \times 100$	$(KWT/FSWT) \times 100$
8	Shell/Fruit (%)	S/F	$((FNWT-KWT)/FSWT) \times 100$	$((FNWT-KWT)/FSWT) \times 100$
9	Oil/dry/Mesocarp (%)	O/DM	$((GMWT+ETWT)-ETFWT)/GMWT \times 100$	Direct capture of Figure O/DM with NMR**
10	Oil/WetMesocarp (%)	O/WM	$((DMWT/(FSWT-FNWT)) \times O/DM)/100$	$((DMWT/(FSWT-FNWT)) \times O/DM)/100$
11	Oil/DryKernel (%)	O/DK	NIL	Direct capture of Figure O/DK with NMR**
12	Wet Kernel	WKWT		$(KWT \times 18.44)$ (Isa, (2011))
13	Oil/Wet Kernel (%)	O/WK	$DKWT/WKWT \times O/DK$	$DKWT/WKWT \times O/DK$
14	Mesocarp Oil/Bunch (%)	MO/B	$(F/B \times M/F \times O/WM)/10000$	$(F/B \times M/F \times O/WM)/10000$
15	Kernel Oil/Bunch (%)	KO/B	NIL	$(F/B \times K/F \times O/WK)/10000$ ***
16	Kernel/Bunch (%)	K/B	$(K/F \times FF/B)/100$	$(K/F \times FF/B)/100$
17	Moisture Content (%)	MC	$((FSWT-FNWT-DMWT)/(FSWT-FNWT)) \times 100$	$((FSWT-FNWT-DMWT)/(FSWT-FNWT)) \times 100$
18	Oil/Fibre (kg/p/yr)	O/F	$((GMWT+ETWT)-ETFWT)/(ETFWT-ETWT) \times 100$	$((GMWT \times ((100-OTDM) \times GMWT))/((100-OTDM)ETFWT-ETWT \times GMWT))$
19	Oil Yield (kg/p/yr)	OY	$(MFFB \times O/B)/100$	$(MFFB \times O/B)/100$
20	Kernel Yield (kg/p/yr)	KY	$(MFFB \times K/B)/100$	$(MFFB \times K/B)/100$
21	Total Economic Product (kg/p/yr)	TEP	$OY + (0.6 \times KY)$	$OY + (0.6 \times KY)$
22	Total Oil (kg/p/yr)	TOT	$OY + (0.5 \times KY)$	$OY + (0.5 \times KY)$

Where:

**BWT** = Bunch Weight  
**SWT** = Spikelet Weight  
**PFWT** = Parthenocarpic Fruit Weight  
**FSWT** = Fruit Sub Sample Weight  
**NOFNUT** = No of Fresh Nut  
**GMWT** = Grind Mesocarp Weight  
**ETWT** = Extraction Thimble Weight  
**DMWT** = Dry Mesocarp Weight  
**WKWT** = Wet Kernel Weight

**STKWT** = Stalk Weight  
**FFWT** = Fertile Fruit Weight  
**ESPKWT** = \* Empty Spikelet Weight  
**FNWT** = Fresh Nut Weight  
**KWT** = Dry Kernel Weight  
**TWT** = Tin Weight  
**FFB** = Fresh Fruit Bunch  
**ETFWT** = Extraction Thimble + Fibre Weight

\* ESPKWT = Empty Spikelet + infertile fruit (colourless and non-oil bearing)

\*\* Trait obtained from NMR

\*\*\* New trait derived from NMR

**TABLE 6 : SAMPLE DATA FOR MESOCARP OIL COMPONENTS DERIVED FROM SOXHLET AND NMR METHOD**

NO	TRIAL_NO	PALM_NO	O/DM			O/WM			MO/B (%)			O/F (%)		
			SOXHLET	NMR	DIFF	SOXHLET	NMR	DIFF	SOXHLET	NMR	DIFF	SOXHLET	NMR	DIFF
1	0.395	45	72.70	72.76	-00.06	40.24	40.28	-0.03	19.07	19.10	-0.03	266.315	267.107	-0.792
2	0.418	331	79.25	79.28	-00.03	55.48	55.50	-0.02	27.95	27.97	-0.02	381.901	382.625	-0.725
3	0.444	1406	77.10	77.18	-00.08	49.29	49.34	-0.05	25.58	25.63	-0.05	336.728	338.212	-1.484
4	0.444	1421	74.19	74.27	-00.08	43.84	43.88	-0.05	20.96	21.00	-0.04	287.485	288.651	-1.167
5	0.444	1492	77.23	77.23	00.00	51.24	51.24	0.00	26.53	26.53	0.00	339.162	339.174	-0.012
6	0.449	489	80.69	80.74	-00.05	60.74	60.78	-0.04	35.73	35.78	-0.05	417.844	419.211	-1.367
7	0.449	511	74.41	74.44	-00.03	51.20	51.22	-0.02	19.63	19.64	-0.01	290.832	291.236	-0.405
8	0.449	533	65.44	65.48	-00.04	29.95	29.96	-0.02	12.76	12.77	-0.01	189.392	189.687	-0.295
9	0.449	543	76.72	76.75	-00.03	27.83	27.84	-0.01	14.39	14.40	-0.01	329.607	330.108	-0.500
10	0.450	540	80.56	80.62	-00.06	57.91	57.95	-0.04	29.35	29.40	-0.04	414.361	415.996	-1.635
11	0.395	251	69.38	69.29	00.09	39.38	39.33	0.05	16.87	16.82	0.04	226.582	225.627	0.955
12	0.395	399	75.12	75.10	00.02	51.50	51.49	0.01	21.33	21.32	0.01	301.929	301.606	0.323
13	0.444	1403	79.92	79.91	00.01	52.80	52.79	0.01	27.48	27.47	0.01	398.068	397.760	0.307
14	0.444	1420	74.20	74.10	00.10	45.87	45.81	0.06	23.51	23.44	0.07	287.642	286.100	1.542
15	0.444	1422	78.35	78.26	00.09	52.41	52.35	0.06	27.52	27.46	0.06	361.818	359.982	1.836
16	0.449	651	81.76	81.73	00.03	55.91	55.89	0.02	30.09	30.06	0.03	448.388	447.345	1.042
17	0.449	486	79.76	79.76	00.00	51.07	51.07	0.00	29.00	29.00	0.00	394.140	394.071	0.069
18	0.449	488	79.20	79.13	00.07	48.66	48.62	0.04	21.04	21.00	0.04	380.835	379.157	1.678
19	0.449	495	79.48	79.47	00.01	51.37	51.36	0.00	23.95	23.94	0.00	387.226	387.092	0.134
20	0.450	539	79.11	79.03	00.08	54.34	54.29	0.05	28.95	28.89	0.06	378.652	376.872	1.780

Where:

**O/DM** = Oil to Dry Mesocarp (%)  
**O/WM** = Oil to Wet Mesocarp (%)  
**MO/B** = Mesocarp Oil to Bunch (%)  
**O/F** = Oil to Fibre (%)

**TABLE 7 : SAMPLE DATA FOR KERNEL OIL COMPONENTS DERIVED FROM NMR METHOD**

NO	TRIAL NO	PALM NO	FT	KWT (gm)	WKWT (gm)	K/F (%)	O/DK (%)	O/WK (%)	F/B (%)	KO/B (%)
1	0.395	93	T	48.11	56.98	13.67	58.93	49.76	57.77	3.93
2	0.395	401	T	47.03	55.70	15.86	58.17	49.11	54.25	4.22
3	0.395	226	D	58.57	69.37	17.32	56.74	47.91	57.93	4.81
4	0.395	258	D	48.01	56.86	14.61	61.93	52.29	66.93	5.11
5	0.395	264	T	58.53	69.32	16.27	57.31	48.39	68.03	5.36
6	0.395	252	T	66.98	79.33	20.61	58.42	49.32	53.56	5.44
7	0.395	251	T	80.40	95.23	23.01	58.41	49.32	61.73	7.00
8	0.397	944	D	49.14	58.20	14.80	54.03	45.62	59.04	3.99
9	0.397	920	D	47.98	56.83	15.36	55.71	47.04	58.07	4.20
10	0.397	975	D	57.94	68.62	18.26	56.70	47.87	49.38	4.32
11	0.397	1026	D	50.40	59.69	16.52	55.11	46.53	60.52	4.65
12	0.397	954	D	62.55	74.08	17.95	56.94	48.07	61.90	5.34
13	0.397	912	D	64.47	76.36	16.63	59.78	50.47	64.53	5.42
14	0.400	1021	D	41.71	49.40	11.90	56.64	47.82	71.38	4.06
15	0.449	588	T	35.07	41.54	10.80	57.24	48.33	76.32	3.98
16	0.449	706	D	46.65	55.25	12.71	56.94	48.07	67.65	4.13
17	0.449	626	D	55.76	66.04	16.93	53.74	45.37	59.45	4.57
18	0.449	648	D	41.62	49.29	14.08	56.25	47.49	72.48	4.84
19	agro	1	T	44.82	53.08	13.10	54.80	46.27	66.80	4.05
20	agro	12	T	52.88	62.63	15.01	57.39	48.45	60.24	4.38

Where:

**KWT** = Dry kernel Weight (gm)  
**WKWT** = Wet Kernel Weight (gm) = Dry Kernel Weight \*118.44 (corrected losses)  
**K/F** = Kernel to Fruit (%)  
**O/DK** = Oil to Dry Kernel (%)  
**O/WK** = Oil to Wet Kernel (%)  
**F/B** = Fruit to Bunch (%)  
**KO/B** = Kernel Oil to Bunch (%)



## CONCLUSION

The Nuclear Magnetic Resonance (NMR) analyzer for the determination of O/DM and O/DK in fresh fruit bunches was found to give accurate results. Comparisons made between O/DM derived from NMR and O/DM by the current method (Soxhlet Extraction) indicated no significant differences. The utilization of the NMR analyzer in this study provides breeders with an option for oil analysis without any usage of n-hexane. As the NMR method does not require any usage of solvent or other chemicals, the need for fume cabinets and expensive disposal procedures is removed. This has direct benefits for several areas of breeding research where current tendencies and legislation require a reduction in the use of hazardous or environmentally unsafe chemicals and solvents.

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