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Quality Assurance of Rice and Paddy Moisture Measurements in Thailand

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Abstract A bilateral comparison in moisture measurement between the National Institute of Metrology Thailand (NIMT) and the Central Bureau of Weights and Measures (CBWM) was organized for quality assuring of rice and paddy moisture measurement in Thailand. The bilateral comparison was conducted by using the same batch of sample and moisture meter as transfer device. It consisted of two parts: moisture measurement in rice and in paddy. A rice moisture meter belonging to CBWM and rice standards prepared at the nominal moisture content of 10 %, 12 %, 14 % and 16 % at NIMT, were used for rice moisture comparison, while a paddy moisture meter belonging to NIMT and paddy standards prepared at the nominal moisture content of 12 %, 14 %, 16 % and 18 % at CBWM, were used for paddy moisture comparison. Both laboratories measured the moisture content of a sample by using the standard method in ISO 712 and used that sample to calibrate a moisture meter by means of the method based on ISO 7700-1. Since the moisture content of the sample can change during the comparison, correction values in moisture content between the standard value and the reading value from the moisture meter are used as calibration results for the comparison evaluation. For the rice moisture comparison, differences in the correction value measured by the two laboratories vary from 0.18 % to 0.46 %, with their combined comparison uncertainty of 0.37 % ($k = 2$). The main contribution to the difference comes from the standard values from both laboratories differing from 0.27 % to 0.53 %, as the rice standard was found to drift in moisture content less than 0.05 %. Similarly to the rice moisture comparison, differences in the correction value

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for the paddy moisture measurement range from 0.08 % to 0.56 % with the combined comparison uncertainty of 0.38 % (k = 2), whereas the stability in moisture content of the paddy sample at NIMT was found to be within 0.12 %.

Keywords Bilateral comparison · Moisture content · Quality assurance

1 Introduction

Since 2004 the Central Bureau of Weights and Measures (CBWM) has established a legal metrology traceability system, standards for calibration, verification and inspection of rice moisture meters in Thailand. Based on OIML R59 [1], the CBWM determines the moisture content of rice standard by using the standard method according to ISO 712 [2] and calibrates its reference standard rice moisture meter with the rice standards based on ISO 7700-1 [3]. Even if the primary standard method was applied and the measurements are metrological traceable, an inter-laboratory comparison with a capable laboratory is still required to ensure the measurement capability of CBWM in rice moisture measurement. However, there is no laboratory capable to measure the moisture content in rice available in this region. Recently, the National Institute of Metrology Thailand (NIMT) has developed the capability in rice moisture measurement and rice moisture meter calibration. Therefore, a bilateral comparison between the national metrology institute and the legal metrology authority is purposed for quality assuring of rice and paddy moisture measurement in Thailand.

In this pilot comparison, both milled rice and paddy are used as samples and two different types of moisture meters are used as transfer devices. Both NIMT and CBWM determine the moisture content of the samples by means of the direct method in ISO 712 and use the rice or paddy standards to calibrate the transfer devices based on the checking procedure in ISO 7700-1.

2 Traceability for Rice Moisture Measurement in Thailand

Based on OIML R 59 [1], the rice moisture content is determined by using the air oven method according to ISO 712:2009 *Cereals and cereal products—Determination of moisture content—Reference method* [2]. The reference standard rice moisture meter is calibrated by comparison with the rice standard according to ISO 7700-1:2008 *Food products—Checking the performance of moisture meters in use—Part 1: Moisture meters for cereals* [3]. The working standard rice moisture meter is calibrated by comparison with the rice standard or reference standard rice moisture meter. Finally, the rice moisture meter is verified or inspected by comparison with the rice standard or working standard rice moisture meter (see Fig. 1) [4].

3 Comparison Description

3.1 Comparison Procedure

In this pilot comparison, both rice and paddy are used as samples and two different type moisture meters are used as transfer devices. NIMT prepared rice standards with

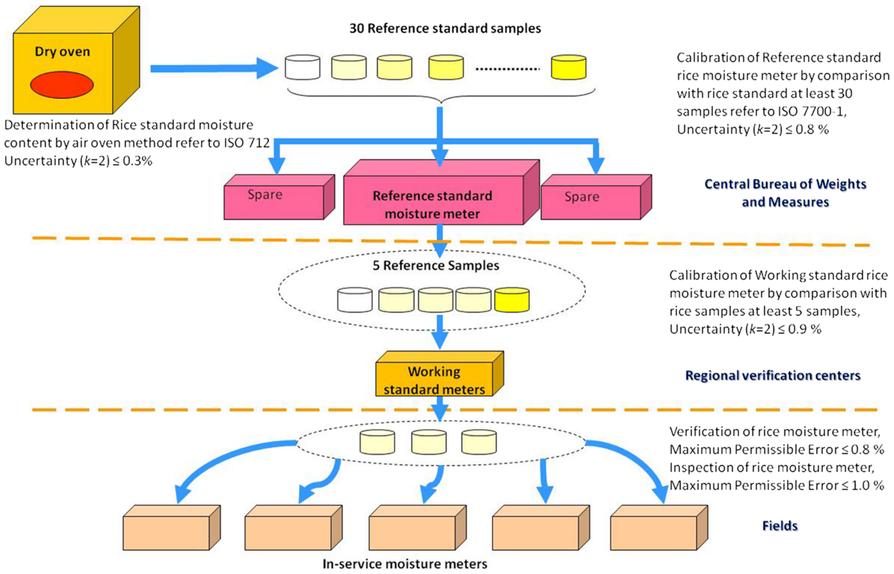

Fig. 1 Traceability chart for rice moisture content measurement in Thailand

the nominal moisture content of 10 %, 12 %, 14 % and 16 %, while CBWM prepared paddy standards with the nominal moisture content of 12 %, 14 %, 16 % and 18 %. For transfer devices, NIMT provided a capacitance-type moisture meter for measurement in paddy (Kett, PM-4502), while CBWM provided a resistance-type moisture meter (Kett, Riceter F-520) for rice measurement. Both of NIMT and CBWM determine the moisture content of the samples by means of direct method in ISO 712 and use the rice or paddy standards to calibrate the transfer devices based on the checking procedure in ISO 7700-1.

3.2 Preparation of Rice and Paddy Standards

For paddy sample preparation, rough paddy samples are collected during the harvest season in the high moisture range of about 26 % to 28 %. Each sample is cleansed using winnower and hand sieves and then divided into several portions, approximately 1 kg per portion and each put into a 1-L glass bottle. The moisture content of each portion is decreased to the nominal moisture content by drying in the oven at 30 °C or 60 °C when the moisture content is lower than 16 %. For transportation, a portion of each paddy standard is packed in a sealed plastic bag. Before starting a measurement, the sample bottle is put on a rolling machine until its moisture content is homogeneous and the temperature of the sample is stabilized in the laboratory.

In case of rice standard, 5-kg portion of rice samples is bought from a local market and divided into several portions, about 500 g per portion. Since the moisture content of the rice samples is initially lower than 14 %, 5 portions of the rice samples are humidified in a climatic chamber at a constant relative humidity of 90 %. Unlike the paddy standard, a portion of rice standard is bottled in a 0.5-L glass bottle for delivery.

3.3 Determination of the Moisture Content Using ISO 712

In this method, a small portion (5 g) of a finely ground sample is heated and dried in an air oven at 130 °C for 2 h. Based on an assumption that only water is evaporated during the drying process, the percent moisture content is calculated from the weight before and after drying as in the following equation

$$MC = \frac{m_0 - m_1}{m_0} \times 100 \tag{1}$$

where MC moisture content, %

m_0 mass of sample before drying, g
m_1 mass of sample after drying, g.

For samples with moisture content larger than 15 %, a sample of slightly greater than 5 g was taken and dried in the oven at 130 °C for 10 min for preconditioning. The weight of the sample before drying and after drying was recorded. After that, it was preceded in the same way for a sample with the normal moisture content. In the case of preconditioning, the percent moisture content is calculated from the weight before and after drying as in the following equation

$$MC = \left(1 - \frac{m_1 \cdot m_3}{m_0 \cdot m_2}\right) \times 100 \tag{2}$$

where MC moisture content, %

m_0 mass of sample before drying, g
m_1 mass of sample after drying, g
m_2 mass of sample before preconditioning, g
m_3 mass of sample after preconditioning, g.

Although the loss-on-drying (LoD) method exploits a fundamental gravimetric principle, its application is empirical in nature. The measurement results may vary depending on drying conditions such as drying time, heating temperature, ambient humidity and especially grain size. To avoid this, NIMT used the same grinder as CBWM.

3.4 Calibration of the Moisture Meters Based on ISO 7700-1

This standard document introduces a comparison between the measurement results of moisture content of reference samples obtained by the moisture meter under test and the reference method based on ISO 712. In principle, the test sample in a bottom was subsampled to determine the moisture content before checking. Then the remaining portion was used to measure its moisture content by the moisture meter for at least 3 times. After that, the used sample was subsampled again to determine the moisture content after measuring. Finally, a correction of the moisture meter was calculated as follows

$$C_i = \frac{MC_1 + MC_2}{2} - MC_i \tag{3}$$

where C_i Correction of the moisture meter under calibration, %

- MC_1 Moisture content of the test sample with the reference method before checking, %
- MC_2 Moisture content of the test sample with the reference method after checking, % and
- MC_i Average moisture content reading by the moisture meter under test, %.

It is important that both the reference sample and the moisture meter are kept at the same room temperature. However, NIMT calibrated the moisture meter at the room temperature of 23 °C, while CBWM calibrated at 25 °C. A difference in moisture content using this method measured by NIMT and CBWM is expected to be 0.2 % [5].

3.5 Uncertainty Estimation

Since both standard documents give no information about the uncertainty estimation of the measurement, the CBWM develops its own measurement uncertainty analysis in accordance with the JCGM 100:2008 "Evaluation of measurement data—Guide to the Expression of Uncertainty in Measurement (GUM)" [6]. More details in the calculation can be found in Ref. 4, and NIMT basically applies to its calculation.

3.5.1 Evaluation of Measurement Uncertainty of the Paddy and Rice Standard

From the mathematical model in Eq. 2, the measurement uncertainty can be analyzed as follows

$$\begin{aligned} u_c^2(M) = {} & \left(\frac{100 \cdot m_1 \cdot m_3}{m_0^2 \cdot m_2}\right)^2 \cdot u_{m_0}^2 + \left(-\frac{100 \cdot m_3}{m_0 \cdot m_2}\right)^2 \cdot u_{m_1}^2 \\ & + \left(\frac{100 \cdot m_1 \cdot m_3}{m_0 \cdot m_2^2}\right)^2 \cdot u_{m_2}^2 + \left(-\frac{100 \cdot m_1}{m_0 \cdot m_2}\right)^2 \cdot u_{m_3}^2 \\ & + \left(\frac{100 \cdot (m_0 - m_1)}{(m_0)^2}\right)^2 \cdot u_{md}^2 + u_C^2 + u_R^2 \end{aligned} \tag{4}$$

where $u_c(M)$ uncertainty in moisture content, %

- u_{m_0} uncertainty in weighing the initial mass of sample, g
- u_{m_1} uncertainty in weighing the final mass of sample, g
- u_{m_2} uncertainty in weighing the mass of sample before preconditioning, g

Table 1 Uncertainty budget for determining the moisture content of the sample with preconditioning

Quantity X_i	Estimate x_i	Standard uncertainty $u(x_i)$	Probability distribution	Sensitivity coefficientc_i	Uncertainty contribution $u_i(y)$
m_0	5.9916	0.00012 g	Normal	13.83 %/g	0.00083 %
m_1	5.6013	0.00012 g	Normal	14.80 %/g	0.00089 %
m_2	6.7798	0.00012 g	Normal	12.23 %/g	0.00073 %
m_3	6.0114	0.00012 g	Normal	−13.79 %/g	0.00073 %
m_d	49.7283	0.00012 g	Normal	1.08 %/g	0.00083 %
u_C	–	0.15	Rectangular	1.00	0.087 %
u_R	–	0.043	Normal	1.00	0.043 %
Combined uncertainty					0.097 %
Expanded uncertainty ($k = 2$)					0.20 %

u_{m_3} uncertainty in weighing the mass of sample after preconditioning, g
u_{m_d} uncertainty in weighing the mass of disk, g
u_C uncertainty due to dryer capability, %
u_R uncertainty due to repeatability, %

For the measurement without preconditioning, Eq. 4 can be written as follows

$$u_c^2(M)=\left(\frac{100\cdot(m_1)}{(m_0)^2}\right)^2\cdot u_{m_0}^2+\left(-\frac{100}{m_0}\right)^2\cdot u_{m_1}^2+\left(\frac{100\cdot(m_0-m_1)}{(m_0)^2}\right)^2\cdot u_{m_d}^2+u_C^2+u_R^2 \quad (5)$$

Table 1 illustrates the uncertainty budget for determining the moisture content of a test portion of paddy sample at NIMT for the case with preconditioning. The expanded measurement uncertainty in moisture content of the paddy and rice standard was estimated to 0.2 % by NIMT while 0.18 % by CBWM.

3.5.2 Evaluation of Uncertainty in Moisture Meter Calibration

Basically, the uncertainty in moisture meter calibration consists of the uncertainty in determination of moisture content by the ISO 712 (u_{712}), an uncertainty due to repeatability of the three times measurements by the moisture meter (u_{repeat}) and the resolution of the moisture meter under calibration (u_{res}). The expanded uncertainty in moisture meter calibration is estimated to 0.24 % by CBWM as shown in Table 2. However, an additional uncertainty contribution was considered at NIMT. Since the test portion was taken to determine the moisture content before and after measurement by the moisture meter, the difference between them was considered as an uncertainty contribution (u_{variance}). The expanded uncertainty in moisture meter calibration is estimated to 0.24 % by CBWM and 0.30 % by NIMT as shown in Table 2.

Table 2 Uncertainty budget in moisture meter calibration at NIMT

Quantity X_i	Standard uncertainty $u(x_i)$	Probability distribution	Sensitivity coefficient c_i	Uncertainty contribution $u_i(y)$
u_{ISO712}	0.10	Normal	1.00	0.100
u_{repeat}	0.075	Normal	1.00	0.075
$u_{variance}$	0.13	Normal	1.00	0.075
u_{res}	0.05	Rectangular	1.00	0.029
Combined uncertainty				0.149
Expanded uncertainty ($k = 2$), %				0.30

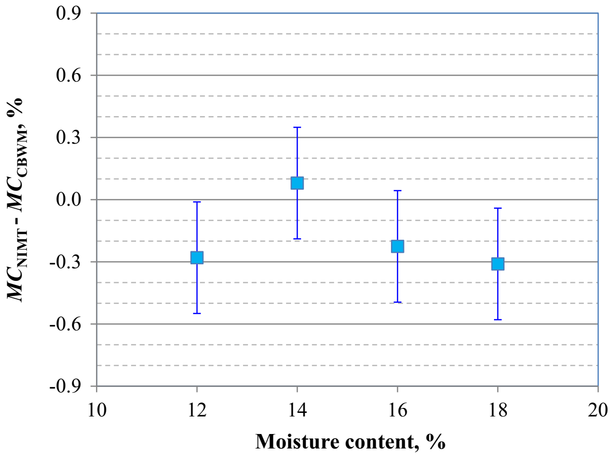

Fig. 2 Difference in moisture content measured in paddy samples by NIMT and CBWM using the ISO 712 along with the expanded uncertainty ($k = 2$) in the error bar

4 Comparison Results

4.1 Moisture Measurement in Paddy

Measurement results for moisture content of paddy samples measured by NIMT and CBWM are compared in Figs. 2 and 3 for standard value determined from the direct method based on ISO 712 and for reading value from the moisture meter PM 4502, respectively.

For direct measurements (Fig. 2), the moisture content of the samples measured by the two laboratories differed by 0.18 % on average. However, the difference at 12 % and 18 % is slightly out of the comparison uncertainty of 0.27 % ($k = 2$). When the maximum value of the instability of the paddy samples of 0.12 % is included in the

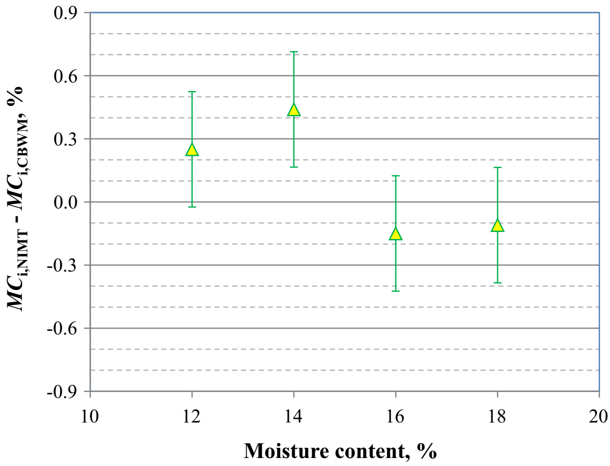

Fig. 3 Difference in moisture content measured in paddy samples by NIMT and CBWM using the moisture meter PM-4502 along with the expanded uncertainty ($k = 2$) in the error bar, UUC: unit under calibration

comparison uncertainty, the measurement results using the LoD method are found consistent.

As can be seen in Fig. 3 for the measurement using the moisture meter PM-4502, the differences are well within their expanded uncertainty of 0.27 % ($k = 2$) except for the measurement at 14 %. Moreover, a difference due to different ambient temperature was not found for this capacitance-type moisture meter. The differences at 12 % and 14 % can be described by the inhomogeneity of the paddy samples as it was roughly estimated to 0.53 % and 0.51 % based on the method in ISO Guide 35: 2006 [7]. However, at this stage, the inhomogeneity is not included in uncertainty evaluation. Here it can be said that paddy samples at low moisture content are not suitable for a comparison in moisture measurement. Considering in terms of correction value, differences at the nominal moisture content are shown in Fig. 4.

Combining measurement uncertainties both in direct and in indirect measurement, the expand uncertainty of differences of the correction value is 0.38 % ($k = 2$), excluding the inhomogeneity. Figure 4 shows that the measurement results in terms of the correction are in agreement within the comparison uncertainty excepting at 12 % moisture content. It is worth noting that even the measurement results using the moisture meter were not in agreement at 14 %, the obtaining corrections were still comparable.

4.2 Moisture Measurement in Rice

In the same way as described in the paddy comparison, measurement results are compared in terms of moisture content determined from the LoD method in Fig. 5, moisture content using the moisture meter Riceter F-520 in Fig. 6 and also correction value plotted in Fig. 7.

The results in Fig. 5 confirm a systematic difference between two laboratories of around 0.34 %, whereas the difference for the measurement value using the moisture

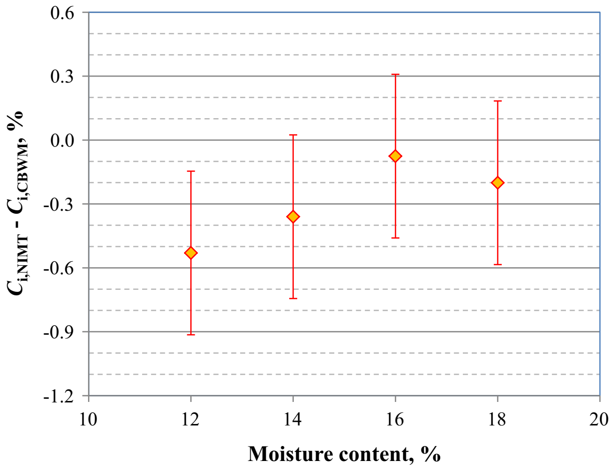

Fig. 4 Difference in correction value for the moisture meter PM-4502 measured by NIMT and CBWM along with the expanded uncertainty ($k = 2$) in the error bar

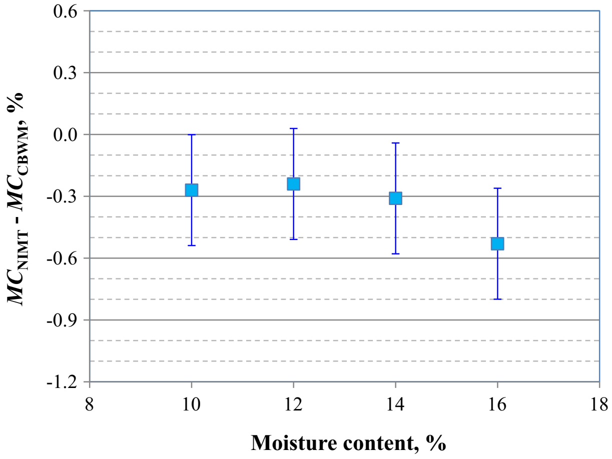

Fig. 5 Difference in moisture content measured in rice samples by NIMT and CBWM using the ISO 712 along with the expanded uncertainty ($k = 2$) in the error bar

meter in Fig. 6 is within 0.19 %, well within the expanded uncertainty of 0.27 % ($k = 2$) as shown in the error bar. Also a difference due to different ambient temperature was not found for this resistance-type moisture meter. As the instability of the rice samples was found to be within 0.05 % during the measurements, this implies the rice samples are more homogeneous than the paddy samples and suitable for a moisture measurement comparison.

In contrast to the comparison results for paddy samples, the measurement results in terms of correction value are not in good agreement, while the average difference is in agreement. As shown in Fig. 7, only the result at 14 % is well within the comparison

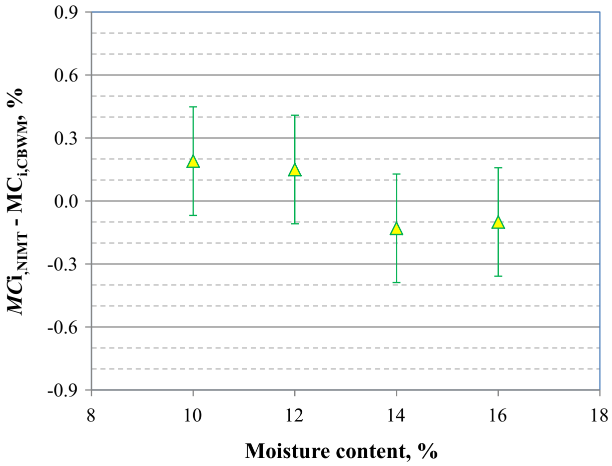

Fig. 6 Difference in moisture content measured in rice samples by NIMT and CBWM using the moisture meter Riceter F-520 along with the expanded uncertainty ($k = 2$) in the error bar, UUC: unit under calibration

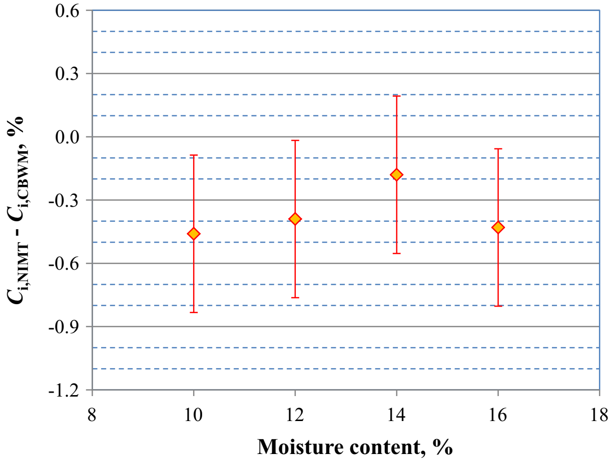

Fig. 7 Difference in correction value for the moisture meter Riceter F-520 measured by NIMT and CBWM along with the expanded uncertainty ($k = 2$) in the error bar

uncertainty of 0.37 % ($k = 2$). However, including the inhomogeneity of the rice sample, the measurement results would be more consistent.

5 Conclusion

This bilateral comparison between NIMT and CBWM was carried out for the moisture measurements in rice and paddy using both the loss-on-drying method in ISO 712 and the indirect method based on ISO 7700-1. The measurement results were compared in terms of the moisture content as determined from the ISO 712 reference method, the moisture reading from the moisture meters and finally the correction of the moisture meters.

The comparison results in paddy moisture measurement were inconsistent due to the poor homogeneity of paddy samples, especially at 14 %. However, such homogeneity has no effect on correction value of the moisture meter under test. For the rice comparison, the comparison results were acceptable as the differences in moisture content using the ISO 712 method were found consistent with the differences in the correction due to good stability and homogeneity of the rice samples. From both the comparison results in rice and paddy, it can be concluded that the measurement results by NIMT are lower than those by CBWM by 0.27 % and 0.34 % on average, whereas the combined uncertainty of the comparison between the two laboratories is 0.37 % ($k = 2$).

In the future, NIMT will study the long-term instability and the inhomogeneity of prepared paddy samples and rice samples in order to develop certified reference material in moisture content. A joint collaboration between NIMT and CBWM will continue to improve the traceability in moisture measurement not only in Thailand but hopefully extending to a wider neighboring region.

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