EURAMET.M.M-S4
BILATERAL COMPARISON OF MASS STANDARDS BETWEEN INRIM AND MCCAA

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Abstract

This report describes the results of the bilateral comparison EURAMET.M.M-S4 (EURAMET 1232) between the Istituto Nazionale di Ricerca Metrologica (INRIM, Italy) and the Malta Competition and Consumer Affairs Authority (MCCAA, Malta).
The results of the comparison will be used to support the Calibration and Measurement Capability (CMC) declaration of MCCAA in the field of mass standards calibration.
INRIM was the pilot laboratory for this bilateral comparison. For this comparison the travelling standards were nine mass standards having the following nominal values: 50 kg, 5 kg, 1 kg, 200 g, 50 g, 5 g, 500 mg, 100 mg and 2 mg.

Introduction

The supplementary comparison Euramet M.M-S4 between INRIM – Italy and MCCA – Malta on nine mass standards, 50 kg, 5 kg, 1 kg, 200 g, 50 g, 5 g, 500 mg, 100 mg and 2 mg, has the aim to support the CMC declaration of MCCAA. The comparison, piloted by INRIM, was conducted during 2012. Participant details and circulation schedule are given in Tables 1 and 2, respectively.

Table 1.Participant laboratories

National Institute of Metrology	Acronym	Technical Contact
Istituto Nazionale di Ricerca Metrologica Mechanical Division Strada delle Cacce, 91 10135 Torino ITALY	INRIM	Andrea Malengo a.malengo@inrim.it Tel: + 39 011 3919 946 Fax: 39 011 3919 937
Malta Competition and Consumer Affairs Authority – Standards and Metrology Institute Kordin Business Incubation Centre Industrial Estate, Kordin, Paola, PLA 3000 MALTA	MCCAA	Nicola Testa nicola.testa@mccaa.org.mt Tel. +356 23980176

Table 2. Time schedule

Order	Country	Date
1	Italy	From 14-05-2012 to 01-06-2012
2	Malta	From 07-06-2012 to 01-08-2012
3	Italy	From 05-09-2012 to 04-10-2012

INRIM provided the travelling standards, whose characteristics are shown in Table 3.

The density of the 50 kg mass standard was estimated from the material specification. On the basis of the MCCAA target uncertainty, the stated associated uncertainty has been considered sufficient.

Table 3. Travelling mass standards

Nominal Value	Density at 20 ºC kg/m^3	Standard uncertainty (k=1) kg/m^3	Height of centre of gravity above base mm
2 mg	7 930 (estimated)	7	-
100 mg	7 930 (estimated)	7	-
500 mg	7 930.7	2.5	-
5 g	7 930.1	2.5	2.5
50 g	7 932.5	0.4	14.0
200 g	7 930.7	0.08	25.0
1 kg	7 966.36	0.03	30.5
5 kg	7 880.5	0.2	63.7
50 kg	8 000 (estimated)	15	120

Measurement results

The travelling standards were measured at INRIM, before and after the circulation, in order to check the mass changes during the comparison. The measurements and the differences $\Delta m = m_{final} - m_{initial}$ are shown in Table 4.
In most of the cases the changes were small enough compared to the claimed uncertainties. Only the 200 g mass standard, due to a change of Δm= 0.006 mg has been considered unstable. For the 200 g mass standard, an additional uncertainty ($u_{drift} = \Delta m/2\sqrt{3}$ =0.001 7mg) has been taken into account among the uncertainty contributions (see Table 7).

Table 4. INRIM measurements

Weight	2 mg	100 mg	500 mg	5 g	50 g
Initial Mass /g	0.001 997 8	0.100 012 2	0.500 013 8	4.999 935 2	50.000 105 6
Final Mass /g	0.001 997 6	0.100 012 4	0.500 013 6	4.999 935 6	50.000 105 8
Δm/mg	-0.000 2	0.000 2	-0.000 2	0.000 4	0.000 2

Weight	200 g	1 kg	5 kg	50 kg
Initial Mass /g	200.000 334	1 000.000 778	5 000.001 607	50 000.043 8
Final Mass /g	200.000 328	1 000.000 782	5 000.001 583	50 000.044 0
Δm/mg	-0.006	0.004	-0.024	0.2

The results of the bilateral comparison (true mass m and conventional mass m_c) are shown in Table 5. The INRIM results are calculated as mean values between the two measurements of Table 4. The relevant plots are shown in Appendix A. The current INRIM CMCs (Calibration and Measurement. Capability) relevant to the range of this comparison are shown in Appendix Table 11.

Table 5. Measurement results. For the 200 g mass standard, the expanded uncertainties U in brackets are the values calculated considering the uncertainty contribution u_{drift} .

Weight identification		INRIM		MCCAA		m_{MCCAA}-m_{INRIM} / mg	$U(m_{MCCAA}$-$m_{INRIM})$ / mg	E_n
		Value /g	U (k=2) / mg	Value /g	U (k=2) / mg			
2 mg	m	0.001 997 7	0.000 5	0.001 998 21	0.000 78	0.000 5	0.000 9	0.55
	m_c	0.001 997 7		0.001 998 20				
100 mg	m	0.100 012 3	0.000 9	0.100 012 81	0.001 7	0.000 5	0.001 9	0.27
	m_c	0.100 012 2		0.100 012 68				
500 mg	m	0.500 013 7	0.001 4	0.500 014 26	0.003 0	0.000 6	0.003 3	0.17
	m_c	0.500 013 0		0.500 013 60				
5 g	m	4.999 935 4	0.002 2	4.999 933 5	0.005 4	-0.0019	0.005 8	-0.33
	m_c	4.999 928 8		4.999 926 9				
50 g	m	50.000 105 7	0.006 6	50.000 093	0.012	-0.0127	0.013 7	-0.93
	m_c	50.000 041 9		50.000 029				
200 g	m	200.000 331	0.008 (0.009)	200.000 305	0.037 (0.037)	-0.031	0.038	-0.82
	m_c	200.000 074		200.000 043				
1 kg	m	1 000.000 780	0.018	1 000.000 809	0.166	0.029	0.167	0.17
	m_c	1 000.000 146		1 000.000 176				
5 kg	m	5 000.001 595	0.172	5 000.001 0	1.1	-0.595	1.1	-0.53
	m_c	4 999.990 220		4 999.989 6				
50 kg	m	50 000.043 9	27	50 000.047	54	3.1	60	0.05
	m_c	50 000.043 9		50 000.047				

Uncertainty analysis has been made, for both laboratories, according to the GUM [1]. The uncertainty contributions for each nominal value are shown in Tables 6, 7 and 8. Details about the balances and ancillary instruments used for the calibrations are shown in Tables 9 and 10.

In order to evaluate the degree of equivalence between the participant laboratories, the difference between the reported results $m_{\mathrm{MCCAA}} - m_{\mathrm{INRIM}}$ and the associated expanded uncertainty $U(m_{\mathrm{MCCAA}} - m_{\mathrm{INRIM}})$ have been determined. The normalized error (or compatibility index) E_n for each standard has been also reported as

$$E_n = \frac{m_{\mathrm{MCCAA}} - m_{\mathrm{INRIM}}}{U(m_{\mathrm{MCCAA}} - m_{\mathrm{INRIM}})}$$

As the laboratory measurements are independent (INRIM realizes its own mass scale and MCCAA is traceable to an accredited laboratory DKD), we have

$$U\ m_{\mathrm{MCCAA}} - m_{\mathrm{INRIM}} = 2\ \sqrt{u^2\ m_{\mathrm{MCCAA}} + u^2\ m_{\mathrm{INRIM}}}$$

As for the 200 g mass standard, the uncertainty contribution u_{drift} is considered as a common additional uncertainty contribution, therefore such a term is taken into account as a covariance contribution between estimates, so that

$$U_{200\,\mathrm{g}}\ m_{\mathrm{MCCAA}} - m_{\mathrm{INRIM}} = 2\ \sqrt{u^2\ m_{\mathrm{MCCAA}} + u^2\ m_{\mathrm{INRIM}} - 2u_{\mathrm{drift}}^2}$$

The results are given in Table 5. They are consistent within the reported uncertainties.

Conclusions

The main objective of this bilateral comparison between INRIM-Italy and MCCAA-Malta was to evaluate the uncertainty claimed by MCCAA on the calibration of mass standards. The results of this comparison will be used to support the Calibration and Measurement Capability (CMC) declaration of MCCAA.
The comparison was conducted during 2012 on nine mass standards (50 kg, 5 kg, 1 kg, 200 g, 50 g, 5 g, 500 mg, 100 mg and 2 mg).
From the calculated degree of equivalence between the two participants in the range of this bilateral comparison, it can be noted that results reported by the participants are consistent.

Reference

[1] JCGM 100:2008 - Evaluation of measurement data. Guide to the expression of uncertainty in measurement .

Appendix A

Table 6. Standard uncertainty contributions for 2 mg, 100 mg and 500 mg.

Weight identification	2 mg		100 mg		500 mg	
Uncertainty contribution	INRIM	MCCAA	INRIM	MCCAA	INRIM	MCCAA
Mass of the standard / mg	0.000 2	0.000 3	0.000 4	0.000 75	0.000 6	0.001 25
Density of the standard/kg m^{-3}	10	133	7	160	3	160
Density of the travelling standard/ kg m^{-3}	7	7	7	7	2.5	2.5
Air density/ kg m^{-3}	0.001	0.03	0.001	0.03	0.001	0.03
Balance linearity and sensitivity /mg						
Balance reading (display resolution) /mg	0.000 04	0.000 04	0.000 04	0.000 04	0.000 04	0.000 04
Weighing difference /mg	0.000 15	0.000 22	0.000 2	0.000 22	0.000 3	0.000 22
Drift of mass of the standard /mg		0.000 10		0.000 25		0.000 42
Combined uncertainty /mg	0.000 25	0.000 39	0.000 45	0.000 84	0.000 7	0.001 5

Table 7. Standard uncertainty contributions for 5 g, 50 g and 200 g.

Weight identification	5 g		50 g		200 g	
Uncertainty contribution	INRIM	MCCAA	INRIM	MCCAA	INRIM	MCCAA
Mass of the standard / mg	0.000 95	0.002 5	0.003 1	0.005 0	0.003 6	0.015
Density of the standard /kg m^{-3}	1.9	11	0.2	2	0.08	1.8
Density of the travelling standard / kg m^{-3}	2.5	2.5	0.4	0.4	0.08	0.08
Air density / kg m^{-3}	0.000 24	0.03	0.000 24	0.03	0.000 10	0.03
Balance linearity and sensitivity /mg			0.000 5		0.000 6	
Balance reading (display resolution) /mg	0.000 04	0.000 04	0.000 4	0.000 4	0.000 4	0.004
Weighing difference /mg	0.000 5	0.000 22	0.001	0.000 22	0.001	0.002 2
Drift of mass of the standard /mg		0.000 83		0.001 7		0.005
Drift of the travelling standard /mg					0.001 7	0.001 7
Combined uncertainty /mg	0.001 1	0.002 7	0.003 4	0.006 1	0.004 4	0.018

Table 8. Standard uncertainty contributions for 1 kg, 5 kg and 50 kg.

Weight identification	1 kg		5 kg		50 kg	
Uncertainty contribution	INRIM	MCCAA	INRIM	MCCAA	INRIM	MCCAA
Mass of the standard / mg	0.008 6	0.075	0.070	0.375	1.0	12.5
Density of the standard /kg m^{-3}	0.07	1.8	0.19	1.8	0.25	30
Density of the travelling standard / kg m^{-3}	0.03	0.03	0.2	0.2	15	15
Air density / kg m^{-3}	0.000 10	0.03	0.000 14	0.03	0.000 4	0.03
Balance linearity and sensitivity /mg	0.000 3		0.025		0.05	
Balance reading (display resolution) /mg	0.000 04	0.004 1	0.004	0.041	0.15	0.041
Weighing difference /mg	0.000 5	0.002 2	0.025	0.22	0.3	0.22
Drift of mass of the standard /mg		0.002 5		0.125		4.2
Combined uncertainty /mg	0.009	0.083	0.086	0.56	13.7	27

Table 9. Details of the instruments used for air density determination

Quantity	Lab.	Manufacturer	Type	Range	Resolution	Uncertainty(1σ)
Temperature	INRIM	ASL	F700	0/28 °C	0.002 5 °C	0.01 °C
	MCCAA	Testo	650	–40 / 180°C	0.1 °C	0.1 °C
Pressure	INRIM	Ruska Druck	PPG6620 DPI 142	700 / 1 100 mbar 700 / 1 100 mbar	0.1 Pa 0.1 Pa	2.0 Pa 3.0 Pa
	MCCAA	Testo	525	25 /10 000 mbar	10 Pa	100 Pa
Humidity	INRIM	Michell	S 3000	0 / 30 °C	0.1 °C	0.1 °C
	MCCAA	Testo	650	0 / 100 %	0.1 %	0.6 %
CO_2	INRIM	H&B	URAS	0 /1 000 ppm	1 ppm	20 ppm
	MCCAA	N/A	N/A	N/A	N/A	N/A

Table 10. Details of the balances used for the calibrations

Weight	Lab.	Manufacturer	Type	Maximum load	Resolution /mg	Std. Dev./mg	Manual/ Automatic
2 mg	INRIM	Mettler	UMX 5	5 g	0.000 1	0.000 2	Manual
	MCCAA	Sartorius	CC6	6 g	0.000 1	0.000 5	Manual
100 mg	INRIM	Mettler	UMX 5	5 g	0.000 1	0.000 2	Manual
	MCCAA	Sartorius	CC6	6 g	0.000 1	0.000 5	Manual
500 mg	INRIM	Mettler	UMX 5	5 g	0.000 1	0.000 3	Manual
	MCCAA	Sartorius	CC6	6 g	0.000 1	0.000 5	Manual
5 g	INRIM	Mettler	UMX 5	5 g	0.000 1	0.000 5	Automatic
	MCCAA	Sartorius	CC6	6 g	0.000 1	0.000 5	Manual
50 g	INRIM	Mettler	AH106	100 g	0.001	0.000 5	Automatic
	MCCAA	Sartorius	CC50	50 g	0.001	0.005	Manual
200 g	INRIM	Mettler	HK1000	1 kg	0.001	0.000 5	Automatic
	MCCAA	Sartorius	CC1000S	1 kg	0.01	0.005	Automatic
1 kg	INRIM	Mettler	M one	1 kg	0.000 1	0.000 3	Automatic
	MCCAA	Sartorius	CC1000S	1 kg	0.01	0.005	Automatic
5 kg	INRIM	Mettler	AT10005	10 kg	0.01	0.02	Automatic
	MCCAA	Sartorius	CC10000S–L	10 kg	0.1	0.5	Manual
50 kg	INRIM	INRIM	50 kg	50 kg	0.15	0.25	Automatic
	MCCAA	Mettler	AX64004	64 kg	0.1	0.5	Automatic

Table 11. INRIM CMCs for mass standards calibration from 1 mg to 100 kg

Range			Expanded Uncertainty	
Minimun value	Maximun value	Units	Value	Units
1	100	mg	0.5 to 1.2	μg
0.1	1	g	1.2 to 1.6	μg
1	10	g	1.6 to 5	μg
10	100	g	5 to 12	μg
0.1	1	kg	12 to 28	μg
1	10	kg	28 to 500	μg
10	100	kg	0.5 to 90	mg

Figure 1. Measurement results for 2 mg. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

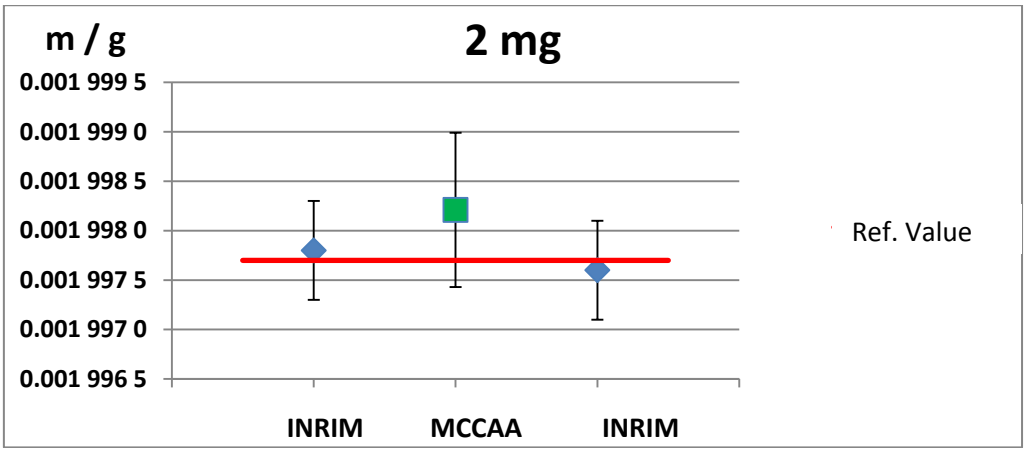

Figure 2. Measurement results for 100 mg. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

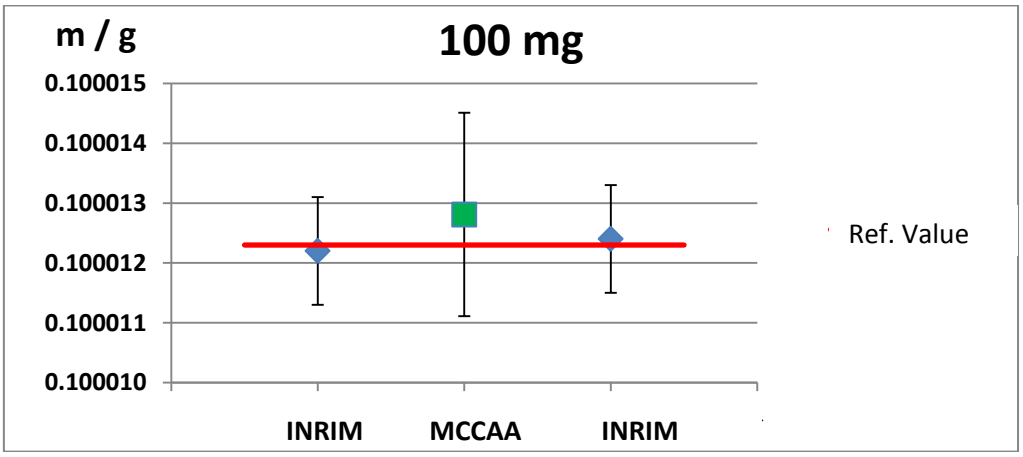

Figure 3. Measurement results for 500 mg. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

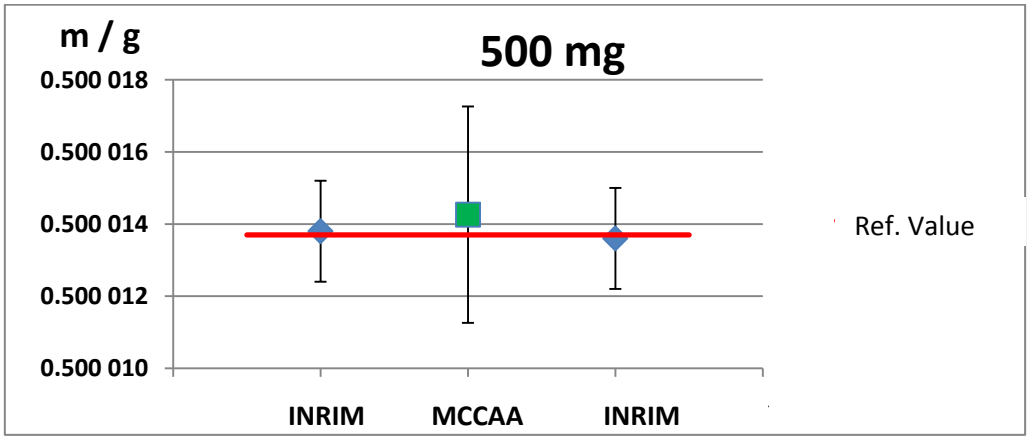

Figure 4. Measurement results for 5 g. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

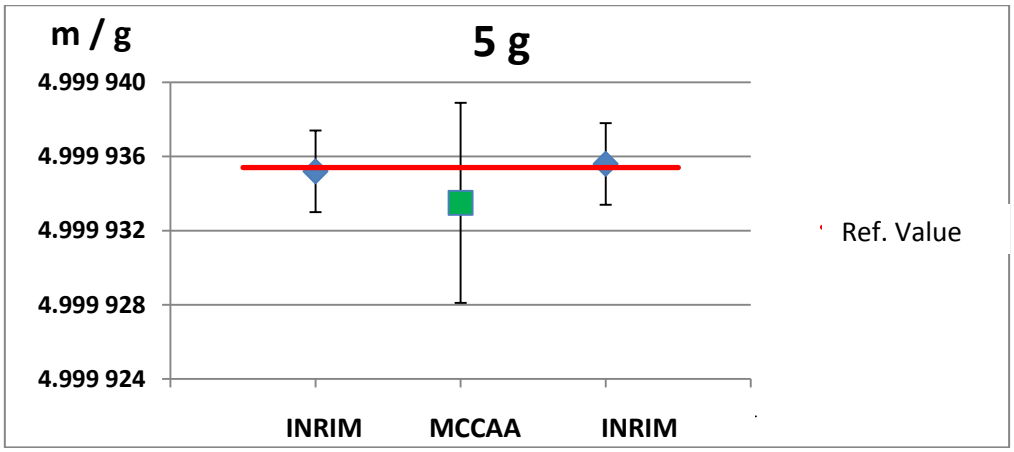

Figure 5. Measurement results for 50 g. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

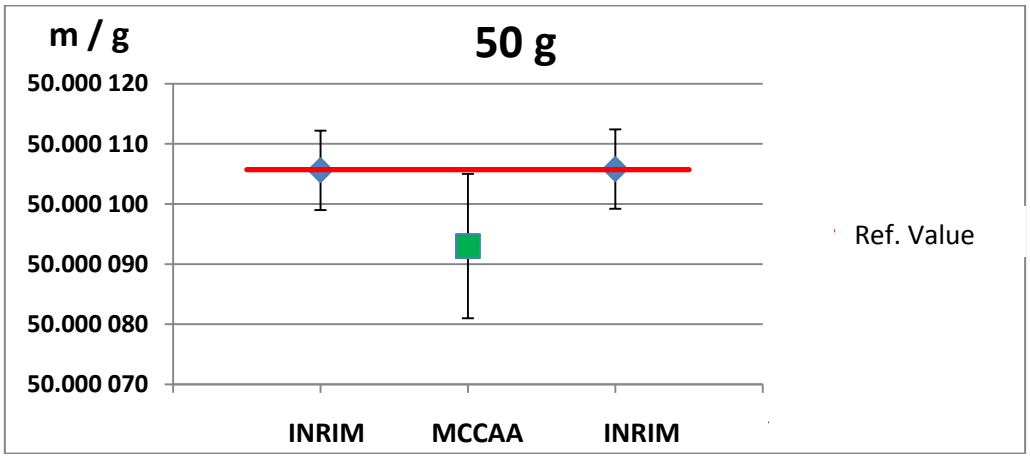

Figure 6. Measurement results for 200 g. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

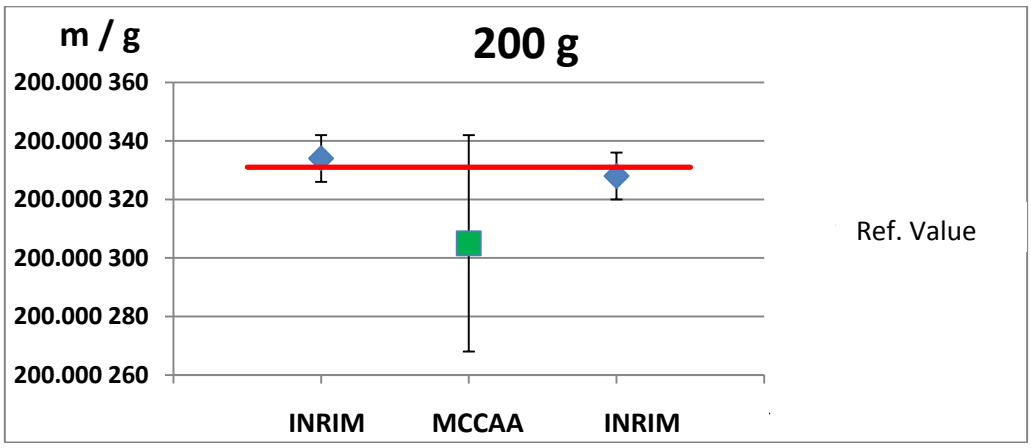

Figure 7. Measurement results for 1 kg. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

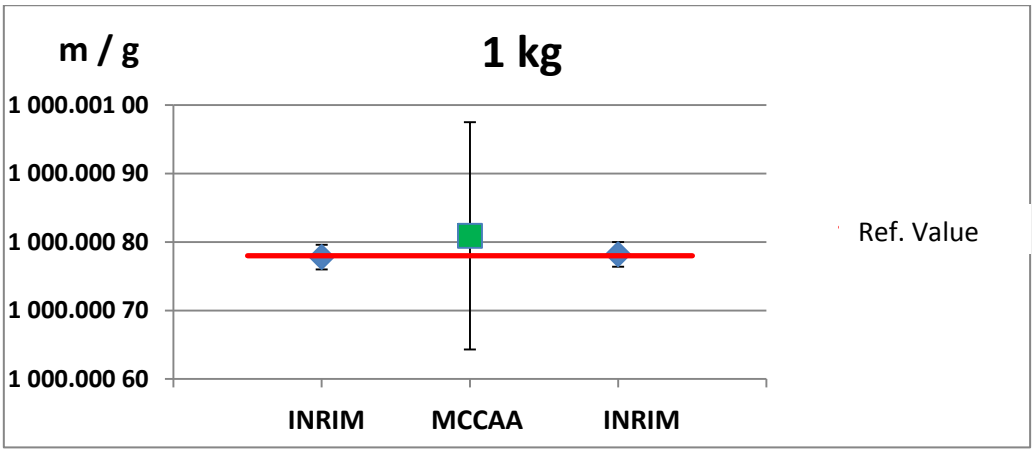

Figure 8. Measurement results for 5 kg. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.

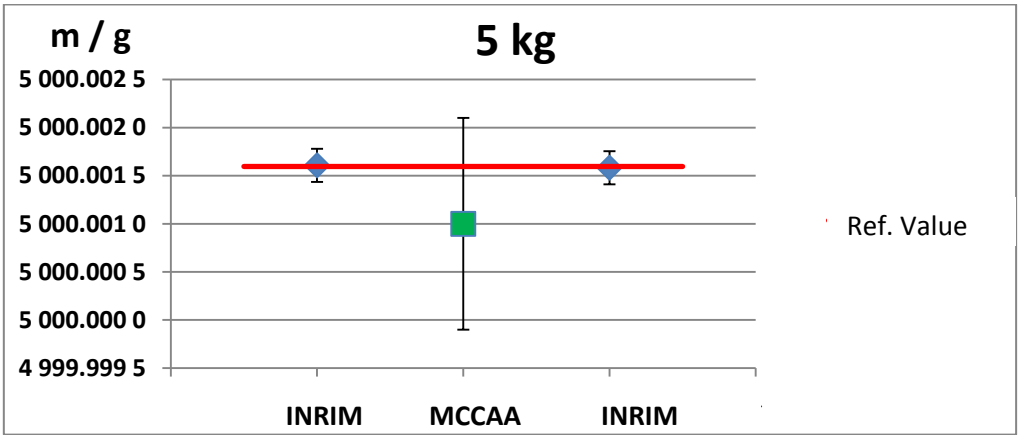

Figure 9. Measurement results for 50 kg. The reference value is determined as mean value of the two INRIM measurements. Error bars show the expanded uncertainties.