



# Certificate of Analysis

## Certified Reference Material

### VORM-1

#### Mealworm powder Certified Reference Material

VORM-1 is a mealworm powder Certified Reference Material (CRM) from the National Research Council Canada (NRC) with information on total trace element and species content, as well as nutritional data listed in Supplementary datasheet. A unit of VORM-1 consists of approximately 18 grams of mealworm powder in an amber glass vial.

Table 1 shows the certified, reference and information values established for VORM-1. The expanded uncertainties associated with the certified and reference values were calculated according to the JCGM Guide [1] and correspond to approx. 95 % confidence ( $k = 2$ ). All listed values are expressed on a dry mass basis.

**Table 1: Mass fractions and expanded uncertainty ( $k = 2$ ) for VORM-1**

Analyte	Mass fraction, mg/kg	Type of value	International recognition of measurement capability (CMC)
aluminium (d,e)	$12.57 \pm 1.38$	certified	<a href="#">TEB-01</a>
arsenic (b,c)	$0.118 \pm 0.010$	certified	<a href="#">MEF-14</a>
inorganic arsenic (as As) (g,h)*	$0.1100 \pm 0.0063$	certified	--
barium (c,d,e)	$3.84 \pm 0.46$	certified	<a href="#">MEF-4</a>
boron (c)	$3.22 \pm 0.68$	reference	<a href="#">MEF-37</a>
bromine (c)	1.26	information	--
cadmium (a,b,c)	$0.069 \pm 0.010$	certified	<a href="#">MEF-16</a>
calcium (c,d,e)	$484 \pm 38$	certified	<a href="#">MEF-17</a>
chlorine (c)	4600	information	--
chromium (a,b,c)	$0.094 \pm 0.012$	certified	<a href="#">MEF-18</a>
cobalt (b,c)	$0.085 \pm 0.014$	certified	<a href="#">MEF-19</a>
copper (c,d,e)	$18.3 \pm 1.0$	certified	<a href="#">MEF-20</a>
iodine (c)	0.018	information	--
iron (a,b,c,d,e)	$72.3 \pm 8.6$	certified	<a href="#">MEF-21</a>
lead (a,b,c)	$0.0636 \pm 0.0088$	certified	<a href="#">MEF-22</a>
magnesium (b,c,d,e)	$3060 \pm 80$	certified	<a href="#">MEF-23</a>
manganese (c,d,e)	$12.22 \pm 0.92$	certified	<a href="#">MEF-24</a>
molybdenum (c,d)	$1.42 \pm 0.18$	certified	<a href="#">MEF-27</a>
nickel (a,b,c)	$0.360 \pm 0.062$	certified	<a href="#">MEF-28</a>

Analyte	Mass fraction, mg/kg	Type of value	International recognition of measurement capability (CMC)
phosphorus (b,c,d,e)	8300 ± 180	certified	--
potassium (b,c,d,e)	9200 ± 200	certified	<a href="#">MEF-29</a>
selenium (a,b,c)	0.216 ± 0.018	certified	<a href="#">MEF-30</a>
selenomethionine (as Se) (f)	0.135 ± 0.010	certified	--
sodium (b,c,d,e)	1330 ± 120	certified	<a href="#">MEF-32</a>
strontium (a,b,c,d,e)	4.71 ± 0.54	certified	<a href="#">MEF-33</a>
sulfur (b,d,e)	3280 ± 240	reference	<a href="#">MEF-39</a>
titanium (c)	0.89	information	--
vanadium (c)	0.12 ± 0.06	reference	<a href="#">MEF-34</a>
zinc (a,b,c,d,e)	127.8 ± 6.4	certified	<a href="#">MEF-35</a>

\*inorganic arsenic is the sum of As(III) and As(V)

## Coding

The coding refers to the instrumental method of analyte determination.

- a** Isotope dilution inductively-coupled plasma mass spectrometry (ID-ICP-MS)
- b** Standard addition inductively-coupled plasma mass spectrometry (SA-ICP-MS)
- c** Inductively-coupled plasma mass spectrometry (ICP-MS)
- d** Standard addition Inductively-coupled plasma atomic emission spectroscopy (SA-ICP-AES)
- e** Inductively-coupled plasma atomic emission spectroscopy (ICP-AES)
- f** Isotope dilution liquid chromatography ICP-MS (ID-LC-ICP-MS) [5,6]
- g** Standard addition liquid chromatography ICP-MS (SA-LC-ICP-MS) [4]
- h** Liquid chromatography ICP-MS (LC-ICP-MS) [4]

## Supplementary data

The accompanying datasheets (available from [doi.org/10.4224/crm.2023.vorm-1](https://doi.org/10.4224/crm.2023.vorm-1)) provide measurement results that were used in this certification campaign. Additional data for total amino acids, free amino acids, fatty acid profile, protein, total carbohydrate, and total dietary fiber are also available.

## Certified values

Certified values are considered to be those for which the NRC has the highest confidence in accuracy and that all known and suspected sources of bias have been taken into account and are reflected in the stated expanded uncertainties. Certified values are the best estimate of the true value and uncertainty.

## Reference values

Reference values are non-certified values for which insufficient data are available to provide a comprehensive estimate of uncertainty to permit their full certification.

## Information values

Information values are those for which insufficient data are available to provide any estimate of uncertainty.

## International recognition of measurement capability

The measurement capabilities supporting these results are registered at the Calibration and Measurement Capabilities (CMC) database of the *Bureau international des poids et mesures* (BIPM) indicating recognition of the measurement certificates by National Metrology Institutes (NMIs) participating in the Mutual Recognition Arrangement (MRA) with the corresponding identifiers. Lists of all registered measurement capabilities in a food matrix can be found in the BIPM database at <https://www.bipm.org/kcdb/>.

## Intended use

VORM-1 is intended for use in the method development, validation, and quality control for the analysis of trace and matrix constituents in high-protein materials.

## Storage and sampling

It is recommended that the material is stored at nominal temperature of +4°C under typical refrigerator conditions. Each vial is packaged in a trilaminate foil pouch. Prior to use, the contents should be well mixed by rotation and shaking, and tightly closed immediately thereafter. Certified values are based on a minimum 250 mg sub-sample.

## Instructions for drying

Determination of dry mass should be performed on a separate sample to avoid contamination. Sample should be dried to a constant mass. The estimated moisture content of VORM-1 is approximately 0.03 g/g.

## Preparation of material

This reference material was prepared from a commercial mealworm powder. The material was blended and bottled in amber glass vials. After bottling, the material was sterilized by subjecting it to a minimum specified dose of 25 kGy gamma irradiation.

## Stability

CRMs with similar matrix have been periodically analyzed for more than ten years at NRC and found to be both physically and chemically stable over this time interval. We expect similar results for VORM-1. Uncertainty components for long and short term stability were considered negligible and are thus not included in the uncertainty budget.

## Homogeneity

The material was tested for homogeneity at NRC. Results from sub-samples (250 mg) were evaluated using Bayesian analysis of variance (ANOVA) [2] to determine both within-unit and between-unit heterogeneity components.

## Uncertainty

Evaluation of the uncertainty associated with certified and reference values was carried out. Included in the overall combined uncertainty estimate are uncertainties in the batch characterization, uncertainties related to possible between-bottle variation, and uncertainties related to inconsistency between the various measurement methods [3]. Further information is presented in the supplementary datasheets [doi.org/10.4224/crm.2023.vorm-1](https://doi.org/10.4224/crm.2023.vorm-1).

## Metrological traceability

Results presented in this certificate are traceable to the International System of Units (SI) through CRMs produced by National Metrology Institutes and gravimetrically prepared standards of established purity. As such, VORM-1 serves as suitable reference material for laboratory quality assurance programs, as outlined in ISO/IEC 17025.

## Quality Management System (ISO 17034, ISO/IEC 17025)

This material was produced in compliance with the NRC Metrology Quality Management System, which conforms to the requirements of ISO 17034 and ISO/IEC 17025. The Metrology Quality Management System supporting NRC Calibration and Measurement Capabilities, as listed in the *Bureau international des poids et mesures* (BIPM) Key Comparison Database ([kcdb.bipm.org/](http://kcdb.bipm.org/)), has been reviewed and approved under the authority of the Inter-American Metrology System (SIM) and found to be in compliance with the expectations of the *Comité international des poids et mesures* (CIPM) Mutual Recognition Arrangement. The SIM approval is available upon request.

## Updates

Users should ensure that the certificate they have is current. For updates please refer to [doi.org/10.4224/crm.2023.vorm-1](https://doi.org/10.4224/crm.2023.vorm-1).

## References

1. Evaluation of measurement data: Guide to the expression of uncertainty in measurement JCGM100:2008. <https://www.bipm.org/en/publications/guides/gum.html>
2. van der Veen AMH (2017) Bayesian analysis of homogeneity studies in the production of reference materials. *Accred. Qual. Assur.* 22: 307-319. [doi.org/10.1007/s00769-017-1292-6](https://doi.org/10.1007/s00769-017-1292-6)
3. Possolo A, Meija J (2022) Measurement uncertainty: A Reintroduction, 2nd edition. *Sistema Interamericano de Metrologia* [doi.org/10.4224/1tqz-b038](https://doi.org/10.4224/1tqz-b038)
4. Gajdosechova Z, Grinberg P, Kubachka K, et al. (2023) Determination of water extractable arsenic species in marine and terrestrial tissue samples; a consensus extraction approach, *in preparation*
5. LeBlanc KL, Le PM, Meija J, Ding J, Melanson J, Mester Z (2021) Preparation and certification of natural and <sup>82</sup>Se-labelled selenomethionine reference materials. *Journal of Analytical Atomic Spectrometry*, 36: 416-428. [doi.org/10.1039/D0JA00411A](https://doi.org/10.1039/D0JA00411A)
6. LeBlanc KL, Kawamoto MS, Le PM, Grinberg P, Nadeau K, Yang L, Nogueira ARDA, Mester Z (2019) Quantitation of Selenomethionine in Multivitamins and Selenium Supplements by High Performance Liquid Chromatography Inductively-Coupled Plasma Mass Spectrometry. *Food Analytical Methods*, 12: 1316-1326. [doi.org/10.1007/s12161-019-01442-6](https://doi.org/10.1007/s12161-019-01442-6)

## Cited by

A list of scientific publications citing VORM-1 can be found at [doi.org/10.4224/crm.2023.vorm-1](https://doi.org/10.4224/crm.2023.vorm-1).

## Authorship

Kelly L. LeBlanc<sup>1</sup>, Patricia Grinberg<sup>1</sup>, Kenny Nadeau<sup>1</sup>, Zuzana Gajdosechova<sup>1</sup>, Christine Brophy<sup>1</sup>, Indumathi Gedara Pihillagawa<sup>1</sup>, Lu Yang<sup>1</sup>, Adrian Simon<sup>1</sup>, Calvin Palmer<sup>1</sup>, Vitoria H. Cauduro<sup>2</sup>, Chawana S. L. Soares<sup>2</sup>, Paola A. Mello<sup>2</sup>, Erico M. M. Flores<sup>2</sup>, Rebecca Sim<sup>3</sup>, Ásta H. E. Pétursdóttir<sup>3</sup>, Andrea Raab<sup>4</sup>, Joerg Feldmann<sup>4</sup>, Stanislav Musil<sup>5</sup>, Tomas Matousek<sup>5</sup>, Kevin Kubachka<sup>6</sup>, Mesay Wolle<sup>7</sup>, Ben Wozniak<sup>8</sup>, Stephen Springer<sup>8</sup>, Hakan Gurleyuk<sup>8</sup>, Juris Meija<sup>1</sup>, and Zoltan Mester<sup>1</sup>.

<sup>1</sup> National Research Council Canada, 1200 Montreal Rd, Ottawa, ON, K1A 0R6, Canada

<sup>2</sup> Universidade Federal de Santa Maria, Santa Maria, Brazil

<sup>3</sup> Matís, Research and Innovation, Vinlandsleid 12, 113, Reykjavik, Iceland

<sup>4</sup> Institute for Chemistry, TESLA - Analytical Chemistry, University of Graz, Universitätsplatz 1/I, 8010, Graz, Austria

<sup>5</sup> Institute of Analytical Chemistry of the Czech Academy of Sciences, Veverí 97, 602 00, Brno, Czech Republic

<sup>6</sup> Forensic Chemistry Center, U.S. Food and Drug Administration, Cincinnati, Ohio 45237, United States

<sup>7</sup> Division of Bioanalytical Chemistry, Office of Regulatory Science, Center for Food Safety and Applied Nutrition, US Food and Drug Administration, 5001, Campus Drive, College Park, MD 20740, USA

<sup>8</sup> Brooks Applied Labs, 18804 North Creek Parkway, Suite 100, Bothell, WA 98011, USA

## Acknowledgements

The contributions of Richard Oliveira are gratefully acknowledged.

## Citation

LeBlanc KL, Grinberg P, et al. VORM-1: Mealworm Powder Certified Reference Material. Ottawa: National Research Council Canada; 2023. Available from: [doi.org/10.4224/crm.2023.vorm-1](https://doi.org/10.4224/crm.2023.vorm-1)

**VORM-1***Date of issue: February 2023**Date of expiry: February 2028***Approved by:**

Zoltan Mester, Ph. D.  
Team Leader, Inorganic Chemical Metrology  
NRC Metrology

**This Certificate is only valid if the corresponding material was obtained directly from the NRC or an Authorized Reseller.**

National Research Council Canada  
Metrology  
1200 Montreal Road  
Building M36, Room 1029  
Ottawa, Ontario K1A 0R6



**Telephone:** 613-993-2359

**Fax:** 613-993-8915

**Email:** [CRM-MRCOttawa@nrc-cnrc.gc.ca](mailto:CRM-MRCOttawa@nrc-cnrc.gc.ca)