
**Solid biofuels — Conversion of
analytical results from one basis to
another**

*Biocombustibles solides - Conversion de résultats analytiques d'une
base en une autre base*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 238, *Solid biofuels*.

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Introduction

In the ISO Standards covering the analysis of solid biofuels, it is generally specified that the determination is intended to be carried out on the air-dried or in air-equilibrated general analysis test sample prepared according to EN 14780. However, in making use of these analyses, it is necessary to express the results on dry basis and sometimes, also on some other basis. The bases in common use for solid biofuels are “air-dried” (sometimes stated as “as determined”), “as received” (sometimes stated “as sampled” or “as delivered”), “dry”, and “dry, ash free”.

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Solid biofuels — Conversion of analytical results from one basis to another

1 Scope

This International Standard gives formulae which allow analytical data relating to solid biofuels to be expressed on the different bases in common use. Consideration is given to corrections that can be applied to certain determined values for solid biofuels prior to their calculation to other bases.

In [Annex A](#), tools for integrity checks of analytical results are given. In [Annex B](#), conversion factors for calculation into other units are given. [Annex C](#) is a guideline for the use of validation parameters as can be found in ISO/TC 238 analytical standards.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 16948:2015, *Solid biofuels — Determination of total content of carbon, hydrogen and nitrogen*

ISO 16994, *Solid biofuels — Determination of total content of sulphur and chlorine*

ISO 18122¹⁾, *Solid Biofuels — Determination of ash content*

EN 14918²⁾, *Solid biofuels — Determination of calorific value*

ISO 18134-1¹⁾, *Solid biofuels — Determination of moisture content — Oven dry method — Part 1: Total moisture - Reference method*

ISO 18134-2¹⁾, *Solid biofuels — Determination of moisture content — Oven dry method — Part 2: Total moisture - Simplified method*

ISO 18134-3¹⁾, *Solid biofuels — Determination of moisture content — Oven dry method — Part 3: Moisture in general analysis sample*

1) To be published.

2) To be replaced by ISO 18125.

3 Symbols and abbreviated terms

The symbols employed in the subsequent clauses are as follows, with the suffixes “ad” (air-dried), “ar” (as received), “d” (dry), and “daf” (dry, ash free), where appropriate.

<i>A</i>	ash (percentage by mass) according to ISO 18122
<i>C</i>	total carbon content (percentage by mass) according to ISO 16948
<i>Cl</i>	total chlorine content (percentage by mass) according to ISO 16994
$q_{p,net}$	net calorific value at constant pressure (J/g) according to EN 14918 ^a
<i>H</i>	total hydrogen content (percentage by mass) according to ISO 16948
<i>M</i>	moisture content (percentage by mass) according to ISO 18134
<i>N</i>	total nitrogen content (percentage by mass) according to ISO 16948
<i>O</i>	total oxygen content (percentage by mass)
<i>S</i>	total sulfur content (percentage by mass) according to ISO 16994
^a	To be replaced by ISO 18125.

4 Principle

In order to convert an analytical result expressed as one basis to another basis, it is multiplied by a factor calculated from the appropriate formulae (see [Table 1](#)), after insertion of the requisite numerical values into the formula in question.

5 Calculations for analyses of solid biofuels

5.1 General

Most analytical values on a particular basis can be converted to any other basis by multiplying it by a factor calculated from the appropriate formula given in [Table 1](#), after insertion of the requisite numerical values into the formula in question. However, for some parameters, there is a direct involvement of the moisture content. In these cases, a correction (as specified in [5.2](#)) of the air-dried result shall be carried out before calculation to dry basis or dry, ash free basis. Also, if a result for these parameters expressed on a dry or a dry, ash free basis is to be recalculated to a moist basis, the corrections stated in [5.2](#) shall be added back to the actual moist basis after applying the appropriate formula from [Table 1](#).

5.2 Extra calculations for hydrogen, oxygen, and net calorific value

5.2.1 Hydrogen

The hydrogen content determined on the air-dried basis (H_{ad} , as analysed) includes both the hydrogen content of the combustible part of the solid biofuel as well as the hydrogen present in the sample as moisture (total hydrogen content). Before calculation to any other basis, the determined hydrogen content, H_{ad} , shall be corrected of the moisture-bound hydrogen by calculation to dry basis, H_d , as shown in Formula (1):

$$H_d = \left(H_{ad} - \frac{M_{ad}}{8,937} \right) \times \frac{100}{(100 - M_{ad})} \quad (1)$$

This hydrogen content, related to the combustible part of the solid biofuel, can be converted to any other basis using the formulae in [Table 1](#).

With the constant factor 8,937, the hydrogen concentration in the water that is present in the sample is calculated. The factor is obtained from the molar formula of water (H₂O) and the atomic weight of hydrogen (1,008) and oxygen (15,999 4).

5.2.2 Oxygen

The oxygen content related to the combustible part of the solid biofuel can be calculated by difference on the dry basis using Formula (2)

$$O_d = 100 - C_d - H_d - N_d - S_d - Cl_d - A_d \quad (2)$$

If high precision is required, the values of S_d and Cl_d should be corrected for eventual remaining contents of sulfur and chlorine in the ash (A_d).

5.2.3 Net calorific value

The net calorific value at constant pressure on a moist basis ($q_{p,net,M}$) includes a correction for the heat of vaporization concerning the actual moisture content, M (M being e.g. M_{ad} or M_{ar}). Before conversion to any other basis, using the formulae in [Table 1](#), this correction corresponding to 24,43 J/g per weight percent moisture ($24,43 \times M$) shall be undone by adding $24,43 \times M$ to the value of the net calorific value. After multiplying this sum with the appropriate formula from [Table 1](#), the obtained value is to be corrected for the heat of vaporization concerning the new moisture content, M^* , by subtracting the value $24,43 \times M^*$. These corrections are illustrated in Formula (3) concerning the conversion of the net calorific value for a moisture content M ($q_{p,net,M}$ in J/g) to the net calorific value for a moisture content M^* (q_{p,net,M^*} in J/g), both at constant pressure.

$$q_{p,net,M^*} = \left[q_{p,net,M} + (24,43 \times M) \right] \times \frac{100 - M^*}{100 - M} - (24,43 \times M^*) \quad (3)$$

For the conversion of e.g. the net calorific value on dry basis ($q_{p,net,d}$ in J/g) to the net calorific value on as received basis, ($q_{p,net,ar}$ in J/g) Formula (3) can be simplified into Formula (4):

$$q_{p,net,ar} = q_{p,net,d} \times \frac{100 - M_{ar}}{100} - 24,43 \times M_{ar} \quad (4)$$

as in this case, $M = 0$ and $M^* = M_{ar}$.

The net calorific value at a constant pressure for a dry sample ($q_{p,net,d}$) is derived from the corresponding gross calorific value at a constant volume according to EN 14918³⁾.

5.3 General formulae for the conversion from one basis to another basis

After applying eventual corrections according to [5.2](#), analytical values on a particular basis can be converted to any other basis by multiplying it by a factor calculated from the appropriate formula given in [Table 1](#), after insertion of the requisite numerical values into the formula in question.

3) To be replaced by ISO 18125.

Table 1 — Formulae for calculating conversion factors to convert analytical results from one basis to another

Given	Wanted			
	As analysed (air-dried) (ad)	As received ^a (ar)	Dry (d)	Dry, ash free (daf)
As analysed (air-dried, ad)		$\frac{100 - M_{ar}}{100 - M_{ad}}$	$\frac{100}{100 - M_{ad}}$	$\frac{100}{100 - (M_{ad} + A_{ad})}$
As received (ar)	$\frac{100 - M_{ad}}{100 - M_{ar}}$		$\frac{100}{100 - M_{ar}}$	$\frac{100}{100 - (M_{ar} + A_{ar})}$
Dry (d)	$\frac{100 - M_{ad}}{100}$	$\frac{100 - M_{ar}}{100}$		$\frac{100}{100 - A_d}$
Dry, ash free (daf)	$\frac{100 - (M_{ad} + A_{ad})}{100}$	$\frac{100 - (M_{ar} + A_{ar})}{100}$	$\frac{100 - A_d}{100}$	

^a Note that the formulae given for calculating results to the “as received” basis can be used to calculate them to any other moisture bases.

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Annex A (informative)

Tools for integrity check

A.1 General

In this Annex, three integrity checks are described. It helps users to evaluate analysis results. These tools are especially useful when larger series of results have to be checked on analysis/typing errors.

A.2 Integrity check based on the carbon results

Calculate the estimate, QB, for the net calorific value at constant pressure on dry basis from the carbon content, using Formula (A.1)^{[4][7][8]}

$$QB \text{ (in MJ/kg)} = 0,2746 \times C_d + 5,79 \quad (\text{A.1})$$

Compare this calculated QB value with the measured value $q_{p,net,d}$ in MJ/kg.

A.3 Integrity check based on the major elements and the ash results

Add the results of the major elements after conversion to their composition on oxide basis. The sum of these oxides (Mash) can then be compared to the ash content (550°C). For samples with a high S and/or Cl content, these values should be added as well. The conversion factor for S is 2,50, while the conversion factor for Cl is 1.

The conversion factors for converting the major elements into their oxide forms are:

Al → Al₂O₃ : 1,89

Ca → CaO : 1,40

Fe → Fe₂O₃ : 1,43

Mg → MgO : 1,66

P → P₂O₅ : 2,29

K → K₂O : 1,20

Si → SiO₂ : 2,14

Na → Na₂O : 1,35

Ti → TiO₂ : 1,67

Calculate the sum Mash (= Major element ash) in % m/m on dry basis according to Formula (A.2) using the element concentrations in mg/kg on dry basis.

$$\text{Mash} = \frac{\left(\text{Al}_d \times 1,89 + \text{Ca}_d \times 1,40 + \text{Fe}_d \times 1,43 + \text{Mg}_d \times 1,66 + \text{P}_d \times 2,29 + \right.}{10\,000} \left. \left(\text{K}_d \times 1,20 + \text{Si}_d \times 2,14 + \text{Na}_d \times 1,35 + \text{Ti}_d \times 1,67 + \text{Cl}_d + \text{S}_d \times 2,50 \right) \right) \quad (\text{A.2})$$

The ratio Mash/ash should be around 1 (from 0,8 to 1,2).

NOTE 1 If the sum of the oxides is less than the ash content, the explanation might be a high content of carbonates.

NOTE 2 With high S and/or Cl content, be aware that more than 50 % of these elements could be lost by ashing at 550 °C.

A.4 Integrity check based on the C H N O and ash results

This check is only possible if the O content has been determined.

Calculate the sum MB (= Mass Balance) according to Formula (A.3):

$$\text{MB} = \text{C}_d + \text{H}_d + \text{N}_d + \text{O}_d + \text{S}_d + \text{Cl}_d + \text{A}_d \quad (\text{A.3})$$

All values are in %.

The MB value should be around 100.

In some types of solid biofuels, relative high amounts of F, Br, or I are found. In that case, the contribution of these elements shall be accounted for as well.

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Table A.1 — Examples of the integrity checks according to A.1, A.2, and A.3

Element	C	H	N	O	Al	Ca	Fe	K	Na	Mg	Si	P	Ti	S	Cl	Ash	$q_{p,net,d}$	MB	Mash	QB
Unit	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	MJ/kg	%	%	MJ/kg
Wood+bark	46,4	6,20	0,01	42,5	44	1 398	46	637	25	175	236	65	3	75	11	0,6	19,2	96	0,4	18,5
Straw	44,4	5,86	0,65	43,7	71	2 829	87	10 770	70	754	11 130	706	25	1 008	1 112	5,6	17,9	100	4,8	18,0
Bark	46,5	5,38	0,56	41,4	536	45 290	297	2 080	115	531	3 175	196	41	741	40	13,3	16,5	107	7,8	18,6
Rapestraw	44,8	5,69	0,34	44,7	34	11 100	25	8 970	653	567	194	551	2	1 943	2 814	4,8	17,7	100	3,9	18,1
Thistle	43,0	5,73	1,03	41,8	411	13 380	238	13 130	12 310	2 308	1 074	795	10	2 002	17 280	9,9	16,8	101	8,3	17,6
Fir without bark	47,8	6,10	0,05	43,9	51	784	15	311	3	103	25	23	3	41	3	0,3	19,2	98	0,2	18,9
Exhausted olive residue	46,0	5,45	1,37	38,7	2 214	13 860	1512	23 870	166	2 955	10 060	1 474	133	1 336	2 074	11,5	19,3	103	9,1	18,4
Wood with glue	50,7	5,78	0,25	42,9	39	4 180	52	944	83	484	80	6	4	167	89	1,5	20,5	101	0,9	19,7
Seaweed	32,3	4,20	2,49	36,1	11 250	19 230	4 440	9 885	11 505	7 620	74 880	1 433	321	20 525	1 847	31,5	12,8	107	32,2	14,6
Coconut shells	49,2	5,54	0,22	45,0	263	697	164	3 410	1 900	575	1 785	128	12	380	1 788	2,1	19,6	102	1,6	19,3
Almond kernels	49,1	6,17	0,22	47,3	108	2 765	237	4 165	49	313	2 430	199	14	177	93	1,9	19,5	105	1,6	19,3
Palm pit kernels	50,8	5,87	0,32	42,8	619	5 460	487	1 240	92	517	8 010	272	31	310	149	3,1	20,2	103	3,1	19,7

NOTE All results are on dry basis,
where
MB are the calculated values according A.3;
Mash are the calculated values according A.2;
QB are the calculated values according A.1.

Annex B (informative)

Tables with units and conversion factors

Table B.1 — Conversion factors 1

	toe ^a	MWh	GJ	Gcal
toe ^a	1	11,63	41,868	10,0
MWh	0,085 98	1	3,600	0,859 8
GJ	0,023 88	0,277 8	1	0,238 8
Gcal	0,1	1,163 0	4,186 8	1
^a tonne oil equivalent				
EXAMPLE 1 toe = 11,63 MWh				

Table B.2 — Conversion factors 2

To convert from	To:	Multiply by
g/cm ³	lb/ft ³	62,427 974
lb/ft ³	kg/m ³	16,018 46
lb/in ³	kg/m ³	27 679,90
lb/ft ³	g/cm ³	0,016 018 46
cm	mil	393,70
joule (J)	BTU	9,484 5 × 10 ⁻⁴
BTU	joule (J)	1 054,350

A mil, also known as a “thou” or a “point”, is a measurement unit of length equal to 0,001 inch (a “milli-inch”, one thousandth of an inch).