INTERNATIONAL STANDARD

ISO 11520-2

First edition
2001-02-01

Agricultural grain driers — Determination of drying performance —

Part 2:
Additional procedures and crop-specific requirements

Séchoirs à grains agricoles — Détermination des performances de séchage —

Partie 2: Modes opératoires supplémentaires et exigences spécifiques à la récolte

Reference number
ISO 11520-2:2001(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this part of ISO 11520 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 11520-2 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 7, *Equipment for harvesting and conservation*.

ISO 11520 consists of the following parts, under the general title *Agricultural grain driers — Determination of drying performance*:

— *Part 1: General*

— *Part 2: Additional procedures and crop-specific requirements*

Annexes C and D form a normative part of this part of ISO 11520. Annexes A, B and E are for information only.

Introduction

ISO 11520-1 covers only those methods for evaluating the drying performance of continuous-flow and batch grain driers to be used when drying rewetted wheat with a moisture content in the range 20 % to 15 % wet basis.

The methods specified in this part of ISO 11520 take account of the following factors:

— a greater range in input and output moisture contents;

— other crops apart from wheat;

— the impracticality of rewetting (dampening) some grains and of differing thermal characteristics.

For correcting the observed evaporation rates to those to be expected at different reference ambient and specified grain conditions, the correction formulae given in ISO 11520-1 are augmented by a series of tables from which correction factors are found by interpolation.

The methods specified are for determining the water evaporation rate which the machines concerned are able to achieve when drying wheat and other grains under the steady-state conditions prevailing during the tests. Methods for correcting observed performance to other input and reference ambient conditions are also specified.

Agricultural grain driers — Determination of drying performance —

Part 2: Additional procedures and crop-specific requirements

1 Scope

This part of ISO 11520 specifies additional procedures and gives guidance for testing and evaluating the drying performance of continuous-flow and batch grain driers for specific grain crops including wheat, barley, oats, maize, rice, sorghum and rape. It supplements the general procedures given in ISO 11520-1 based on drying only wheat over the limited range of moisture content of 20 % to 15 % wet basis.

Methods and data are given for

a) determining the evaporation rate of driers when drying grain crops under steady state conditions, and

b) correcting the main drier performance characteristics, including evaporation rate, grain flow rate, drying time and specific energy and fuel consumption, to reference and other ambient conditions.

Procedures are specified for sampling input and output grain to assess changes in grain quality.

2 Normative reference

The following normative document contains provisions which, through reference in this text, constitute provisions of this part of ISO 11520. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 11520 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 11520-1:1997, *Agricultural grain driers — Determination of drying performance — Part 1: General*.

3 Terms and definitions

For the purposes of this part of ISO 11520, the terms and definitions given in ISO 11520-1 and the following apply.

3.1
reference ambient conditions
ambient conditions of temperature, relative humidity and barometric pressure to which the results of a drier test are to be corrected

3.2
airflow rate
volume of air flowing in unit time per unit volume of grain (this value is also the number of air changes per unit of time)

NOTE There are several ways of expressing airflow rate, but for comparison between driers and crops it is convenient to express it in this way.

3.3
drying period
period during which drying air passes through grain

3.4
cooling period
period during which ambient or near-ambient air passes through grain

3.5
tempering
process by which partially dried grain is held in temporary storage for a number of hours without ventilation, allowing equalization of moisture content within the grain kernel with minimal stress cracking

NOTE When drying rice, a common practice is to cool it to within 2 °C of ambient prior to tempering for a minimum of 4 h. One or more further drying, cooling and tempering cycles may be given.

3.6
dryeration
process by which hot grain is taken directly from a drier and allowed to temper for a minimum of 4 h before being cooled slowly so as to extract additional moisture without using additional fossil fuel

NOTE The hot grain referred to is usually maize or rice, sorghum, soybeans or wheat.

3.7
test period
period during which a continuous-flow drier operating at a single steady state for at least one residence time, or a batch drier completing a single full cycle of drying and cooling, is monitored to enable its thermodynamic performance to be assessed

NOTE In multi-pass drying there may be several test periods.

3.8
wheat
grain of the genus *Triticum*, of which the commercially important species are *T. aestivum* (breadwheat), *T. durum* and *T. compactum* (club wheat)

3.9
barley
grain of *Hordeum sativum* or *H. vulgare*

3.10
oats
grain of *Avena sativa L.*

3.11
naked oats
grain of *Avena nuda L.*, which readily loses the husk at threshing

NOTE Naked oats have a high protein and oil content and the loss of husk makes the kernels prone to rancidity.

3.12
maize
grain of *Zea mays L.*

NOTE This is commonly referred to as corn in North America and some other countries. There are about seven different types of maize distinguished at the "convar" level of classification (between species and cultivar) and within each type there are hybrids having different drying properties. The most widely grown type is the convar *indentata* commonly known as "dent corn".

3.13
rice
grain of *Oryza sativa L.*

3.14
paddy rice
rough rice
rice with the hull or husk still intact

3.15
brown rice
rice kernel from which the hull or husk has been removed during the milling process

3.16
milled rice
white rice
white grain or kernel remaining after the removal of the husk or hull and of the bran (whitening); the embryo or germ may be totally or partly removed and part of the bran may still remain on the grain

NOTE For some end uses, rice may be dried in the milled condition.

3.17
head rice
for brown and milled rice, either a whole or broken grain with length greater than or equal to three-quarters of the average length of a whole or unbroken grain

3.18
full head rice
unbroken head rice

3.19
broken rice
either brown or milled rice grain which has less than three-quarters of the average length of a full head grain

3.20
sorghum
grain of *Sorghum vulgare Pers*

NOTE Types of cultivated grain sorghum include kaffir corn, milo and durra (Africa), feteritas (Sudan), shallu, jowar, cholum and “Indian millet” (India), and kaoliang (China).

3.21
rape (canola)
seeds of *Brassica napus* or *B. campestris* (also known as *B. rapa*)

NOTE Canola and rapeseed are both members of the same botanical family. The designation “canola” has been established by Canada and is applicable to varieties that meet the canola standard for the level of erucic acid and glucosinolates in the seed. From the drying performance point of view, there is no evidence of any difference in drying rates or drying characteristics between rapeseed and canola.

4 Symbols and abbreviated terms

These are given in Table 1.

Table 1 — Symbols and abbreviated terms

Symbol	Description	Unit
B	rated output	kg/s
E	water evaporation	kg
E'	water evaporation rate	kg/s
F	fuel consumption	kg/s
G	holding capacity of drier	kg
J	specific fuel consumption	kg/kg
K	factor for correcting evaporation (defined in 7.2.3)	—
M	moisture content of grain, wet basis (m.c.w.b)	%
N	anticipated number of test periods	dimensionless
Q	specific heat consumption	J/kg
S	specific energy consumption	J/kg
V	volumetric capacity of drier	m^3
W	energy consumption	J
q_v	air volume flow rate	m^3/s
$c_{1...3}$	coefficients in Equation E.1	—
$d_{1...3}$	coefficients in Equation E.2	—
c_{pa}	specific heat of air at constant pressure	$kJ \cdot kg^{-1} \cdot K^{-1}$
c_{pw}	specific heat of water vapour at constant pressure	$kJ \cdot kg^{-1} \cdot K^{-1}$
d	depth of grain bed	m
f	face area at point of air entry to grain bed	m^2
h	specific enthalpy	J/kg
i	coefficient in Equation E.3	—
m	mass of grain in a single batch or passing through a continuous-flow drier in a test run	kg
m'	mass flow of grain	kg/s
n	exponent in Equation E.3	—
p	pressure or pressure drop	Pa
$s(y)$	standard error of mean of variable y	—
t	duration of test period	s
ρ	density	kg/m^3
τ	grain residence time in drier	s
Other subscripts		
e	electrical	
f	final, at drier exit	
i	initial, at drier inlet	
o	observed value	—
s	corrected value at reference or specified conditions	
p	predicted (for model)	
sys	drier system of ducts and plenum chambers	
t	thermal	

5 Test procedure

5.1 General

This clause shall be used in conjunction with clause 7 of ISO 11520-1:1997.

NOTE For the general principle of the tests, test equipment and preparation for testing, see clauses 5, 6 and 7 respectively of ISO 11520-1:1997

Driers are most often used to dry grain which is physiologically ripe and for which the variation in moisture content (m.c.) at harvest is largely a function of ambient weather conditions. For the purposes of a drier test, such grain can normally be rewetted artificially and the test itself conducted more conveniently outside the harvest period. One advantage of this is that the variation in moisture content of the wet grain is usually very small, i.e. less than ± 0,5 % wet basis (w.b.). This is important for minimizing uncertainty in the results.

However, some crops (e.g. maize in France) are harvested at moisture conditions in excess of those to which the grain can reasonably be rewetted and the test has to be conducted during the harvest. In these cases there may be considerable variation in the moisture content of the wet grain and residence times may be large.

Clause B.4 of ISO 11520-1:1997 prescribes procedures for estimating the uncertainty (or level of confidence) in derived performance measures. Variation in ingoing moisture content is an important component of the determination of uncertainty. The uncertainty in determination of the evaporation rate and related quantities increases if too little moisture reduction is achieved (see annex A). A moisture reduction of more than four percentage points is therefore advisable. Provisions are given in 5.4.

5.2 Test period

The test period shall normally be a minimum of one residence time in a continuous flow drier or one drying and cooling cycle in a batch drier.

ISO 11520-1 does not make a direct requirement of the length of the test period, although experience has shown that, for a continuous-flow drier, 1 h is normally sufficient provided that

a) 1,5 residence times are allowed for stabilization, and

b) sampling of the input grain begins prior to the start of the test period, so that the initial moisture content of the grain that will leave the drier during the test period is known.

Where good estimates of the mass flow rate and the measured capacity are available, calculate the residence time using the formulae given in 10.2.2 of ISO 11520-1:1997. For these formulae, the rated output, B (in kilograms per second), may be used in place of the observed mass flow of grain q_m. Otherwise, Table 2 may be used to provide a guide to the expected residence time.

Table 2 gives a guide to approximate residence times (in hours) for combinations of airflow, drying air temperature, moisture removed and specific energy consumption, calculated for a final moisture content of 15 %.

5.3 Frequency of sampling grain

5.3.1 Continuous flow driers

Unless the range of variation in the moisture content of input grain is known to be less than 1 % w.b. (see annex A), take a minimum of 20 samples from the ingoing and outgoing grain streams of a continuous-flow drier at a frequency such that they are spaced evenly over the test period.

Clause 7 of ISO 11520-1:1997 requires sampling of both ingoing and outgoing grain streams at a frequency providing at least 12 samples of each, spaced evenly over the test period. For rewetted wheat in which the range of variation is less than 1 % w.b., these prescriptions have given good accuracy for drying from 20 % w.b. to 15 %

w.b., but are not adequate for all crops. The aim is to reduce the standard error of the mean to ensure an accuracy of estimation of the evaporation rate of ± 5 % (see annex A and Figure A.2).

Ingoing samples will need to correspond to the grain exiting from the drier during the test period (see 7.1 of ISO 11520-1:1997). Some grain samples taken will therefore later be found to be unnecessary, although their additional use in rapid moisture tests may well have given essential information on the progress of stabilization.

Table 2 — Guide to drier residence times

Moisture removed	**Specific heat energy consumption**	**Residence time** h					
		Specific air volume flow rate $m^3 \cdot s^{-1} \cdot m^{-3}$					
		0,3			**3,0**		
		Drying air temperature					
% w.b.	MJ/kg water evaporated	40 °C	90 °C	140 °C	40 °C	90 °C	140 °C
5	4	7	4	2	0,6	0,2	0,1
	10	17	7	5	1,4	0,5	0,4
25	4	34	13	9	3	1,1	0,7
	10	85	33	23	7	3	2

5.3.2 Batch driers

Because of the greater variability of moisture content that might occur in the output stream from a batch drier, a minimum of 50 samples of the output grain shall be taken.

5.4 Moisture removal

Except for multi-pass drying, a minimum of four percentage points of moisture content shall be removed in each test period. To maintain reasonable accuracy on the estimation of evaporation rate (see annex A), this minimum shall be increased in line with the variability in the ingoing moisture content in accordance with Table 3 or Figure A.3.

Moisture content prescriptions for specific crops are discussed in annex B.

Table 3 — Minimum moisture removals

Range in ingoing moisture content % w.b.	**Minimum moisture removal** % w.b.
0,5	4
1	5
2	8
3	10
4	19
5	23

5.5 Grain dampening

Unless it is freshly harvested (i.e. less than 6 wk from harvest), cereal grain shall not exceed 17 % m.c.w.b. before dampening, and shall not have received more than one drying treatment.

The procedure for dampening is described in 6.3.2 of ISO 11520-1:1997.

Experience has shown that Canadian varieties of wheat, barley and canola can be dampened to 25 % w.b., 25 % w.b. and 20 % w.b., respectively.

5.6 Procedure for a multi-pass test

5.6.1 General

This procedure specifies the additional steps necessary for a multi-pass test.

5.6.2 Quantity of grain

Calculate the minimum quantity of grain for one test using the formula given in 7.2 of ISO 11520-1:1997, with the difference that, in this case, N represents the number of passes and t is the time for each pass. If more than one multi-pass test is to be conducted, multiply the formula by the number of such tests.

5.6.3 Outline procedure for continuous flow driers

Fill the drier, run it as for a single pass, and direct the output grain to a discard store. At the start of the test period, direct the output grain to the test period store. When the test period is complete, direct the output grain to a buffer store and continue drying without adjustment until all the grain has passed through the drier.

Cool the grain that is in both the test period store and the buffer store to within 2 °C of ambient temperature, and temper it for 4 h.

Fill the drier with the grain from the previous test period and sample the input grain for use in calculating evaporation during the previous test period. Restart the drier, direct the grain to the discard store and continue sampling the input. When the test period store is emptied, switch to feeding from the buffer store.

When the moisture content of the drier output grain has stabilized, start a new test period by switching the grain to the test period store. When the test period is complete, direct the output grain to a new buffer store and continue drying until all the grain has passed through the drier.

Repeat the procedure until all passes have been completed.

5.6.4 Outline procedure for batch driers

5.6.4.1 Grain stationary

A drier in which the grain remains stationary during drying shall be emptied between successive drying periods, taking samples for moisture content at input and output as in a single-pass test.

The purpose of removing the grain during rest periods is to aid the process of moisture equalization and destroy any moisture gradient.

5.6.4.2 Grain recirculating

A drier in which the grain is recirculating during drying shall not be emptied during rest periods. Moisture content at the end and beginning of each test period shall be assessed on the basis of samples taken from the recirculating grain stream.

6 Grain quality

6.1 General

It is assumed that good quality grain will be used in a drier test. It is therefore important that its properties exceed the minimum national limits for the grain concerned. Where, as in the US and Canada, grain is categorized into grades, the aim should be to use grain satisfying Grades 1 and 2.

NOTE A useful summary of cereal grain quality standards worldwide is given by Kent and Evers [1].

6.2 Input grain

6.2.1 All grains

Determine the moisture content of those samples taken from the input grain stream during the test period.

Record any relevant detail of grain origin or provenance, and the variety, hybrid or both.

Either

a) obtain a 2 kg sample of the input grain as specified in 6.3.1 of ISO 11520-1:1997, or,

b) if the grain is freshly harvested and there is no static bulk, take samples from the input grain stream additional to those being taken to monitor moisture variation with time.

If the grain is to be dampened, obtain a 2 kg sample both before and after dampening.

Using a sample divider, remove from each 2 kg sample a 100 g subsample. Determine the moisture content of the samples.

Dry the remainder of the 2 kg sample or samples with unheated air in a laboratory drier until moisture contents of approximately 15 % w.b. and 10 % w.b. are reached for the cereal seeds and oilseed rape, respectively.

Determine the mass per hectolitre (bulk density) using a calibrated instrument (chondrometer).

Draw subsamples of sufficient size for the determination of mass per 1000 grains, and of purity and germination using ISTA procedures [2].

NOTE 1 The ISTA procedures contain instructions for checking that the averaged results of purity and germination tests fall within prescribed tolerances. If they do not, retest procedures are to be followed. It is particularly important to accurately assess germination capacity because this property is a good guide to quality in general and can be a sensitive indicator of heat damage during drying. (See also 6.2.2.)

NOTE 2 In barley, seed dormancy may be broken by drying.

6.2.2 Wheat for baking

Depression in germination (6.2.1) shall be taken as an indication of damage to baking quality.

NOTE A simple and rapid test for heat damage to protein has been shown to be a useful guide to baking quality.

6.2.3 Maize

From the remainder of the 2 kg sample, draw four samples each of 100 grains. Examine the individual kernels on a grain viewer and count the number of cracked grains. Express the number of cracked grains as the mean of the four samples.

NOTE Cracked grains reduce the value of maize for wet milling.

6.2.4 Rice

6.2.4.1 From the remainder of the 2 kg sample, draw four samples each of 100 grains. Carefully husk by hand, examine the individual kernels on a grain viewer and count the number of cracked grains. Express the number of cracked grains as the mean of the four samples.

6.2.4.2 From the remainder of the 2 kg sample, draw a further four samples each of 200 g and process through a laboratory husker and whitener. From the output from this machine:

a) draw 100 g samples of brown rice and determine the number of broken grains;

b) take four samples each of 100 grains and determine the number of cracked grains as given in 6.2.4.1;

c) return the material to the remainder of the 200 g samples passed through the husker.

Separate sufficient whole grains of husked rice to determine the mass per 1 000 grains of the brown rice. Return the grains to the sample.

Using the laboratory whitener, mill the brown rice and separate the head rice and broken rice from the rest of the grain materials. Weigh each component, in grams. Calculate the head milled rice recovery.

Draw four 100 grain samples of the milled rice and examine them for any damage such as scorching, gelatinization or discoloration that may be due to excessive heat. Record the percentage of heat-damaged grains.

6.3 Output grain

6.3.1 All grains

Determine the moisture content (see 6.2.1) of those samples taken from the output grain stream during the test period.

Combine the remainder of these samples to produce one or more samples of 2 kg representative of the output grain. If the moisture content of the output grain is not close to 15 % w.b. for cereals or 10 % w.b. for rapeseed, either use a laboratory drier or allow it to equilibrate in a laboratory.

Determine the mass per hectolitre, the mass per 1 000 grains, and the purity and germination as given in 6.2.1.

To determine whether any reduction in germination between the input and output grain is significant at the 2,5 % level of probability, use Table C.1 in annex C.

NOTE Samples with low initial germination are likely to exhibit much more depression of germination than those with high initial germination.

6.3.2 Wheat for baking

Proceed as for 6.2.2.

6.3.3 Maize

Determine the percentage of cracked grains as in 6.2.3. Express the increase in cracked grains from input to output as a percentage of the input.

6.3.4 Rice

Follow the procedure of 6.2.4. Express the values for the output grain as a percentage of those for the input grain.

