FACTORS FOR CONVERTING BUSHEL WEIGHT TO HECTOLITER WEIGHT FOR SIX CEREAL GRAINS, FLAX, AND SOYBEANS[1]

W. T. GREENAWAY[2,3], C. A. WATSON[2,4], and G. DAVIS[5]

ABSTRACT

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Factors for converting test weight (lb/bu) to hectoliter weight in kilograms for six cereal grains, flax, and soybeans, and vice versa, are reported. The conversion factors are based on experimental data and, except for corn and soybeans, they are higher than the theoretical.

Test weight, or weight per bushel (1,2), probably evolved from simple beginnings dating back to ancient Sumerians and Babylonians living in the valley of the Tigris and Euphrates rivers about 4000 B.C. Pyler (3) relates the discovery of a clay tablet made in 2600 B.C. which contains a proclamation fixing the fee of priests performing burial rites at 3 urns of beer, 80 pieces of bread, a bed, and a young goat. Since the arts of baking and brewing were known at that time, undoubtedly methods for measuring grain properties existed, including perhaps a forerunner of the bushel weight test. The term "bushel" is used frequently in the Old Testament.

An extensive search of the literature and correspondence with numerous scientists in several countries revealed little about the origin and design of early test weight devices or any information of the test as it might have been performed in the 17th or 18th centuries. Since most things in early U.S. history came from England, some form of a test weight instrument probably did also.

The history of test weight is intimately connected with the history of grain standards. Grain Exchanges were the first to establish corn standards in July, 1857. Fifty-nine years before the federal grain system was established by passage of the Grain Standards Act in the U.S. Congress in 1916, Combs (4) stated, "Grain grading was invented by grain dealers themselves. They had grain grades long before they even had grain inspectors and they had them fifty years before they had moisture testers."

A test weight device was used in Milwaukee, Wis., in 1858 to record the first test weight as a grading factor for spring wheat (5). The Chicago Board of Trade, founded in 1848, adopted test weight in 1859 (5) as a factor for spring wheat. They established that Club wheat was not to weigh less than 60 lb/bu; No. 1 wheat, 56 lb/bu; Standard wheat, 50 lb/bu; and Rejected wheat, 40 lb/bu. The Canadian Grain Commission, Winnipeg, Manitoba, Canada, uses an

[1]Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

[2]Research Chemists, North Central Region, Agricultural Research Service, U.S. Grain Marketing Research Center, 1515 College Ave., Manhattan, KS 66502.

[3]Present address: 516 Westview Drive, Manhattan, KS 66502.

[4]Present address: Hard Red Spring and Durum Wheat Quality Laboratory, ARS, USDA, Department of Cereal Chemistry and Technology, North Dakota State University, Fargo, ND 58102.

[5]Research Assistant, Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506.

imperial pint measure and a Cox funnel to give uniform packing. The grain is leveled with a round striker. For wheat, the weight of the grain is multiplied by 64 and a factor of 1.9 lb is added to give results equivalent to the Avery chrondrometer method. Results are reported in lb/imperial bushel. The Canadian Grain Commission also determined hectoliter weight using a Schopper chrondrometer equipped with a 0.25-liter container. The weight of the grain is converted to kilograms/hectoliter using appropriate conversion tables. The device is essentially the same as the one we used to make the tests herein described.

In a personal communication from L. P. Reitz, Agricultural Research Service, U.S. Department of Agriculture (retired), he says there are other types of test weight devices than the one developed by the USDA in 1916. The McGuirk test weight balance is an apparatus used at the Liverpool, England Commercial Trade Association. The value obtained is an imperial bushel weight and is 3/4 lb lower than that obtained on the Schopper Louis 20 liter instrument used by the London Corn Trade Association. A third method is the Sommer and Runge balance, used routinely. However, the results by this method differ significantly from the Schopper Louis method. The German Normal Exchungs Kommission prepared a conversion table to equate the results.

Dr. Reitz says further, "Test weight has been a useful measurement to plant breeders, millers, and merchants for a long time. Breeders use it as a general guide to a combination of characteristics which include kernel plumpness, density, surface features, brush development and probably kernel shape."

Some scientists in the U.S. regard test weight of wheat as a rough measure of flour yield. This may have been true several years ago when only a few varieties were grown; however, today the number and types of varieties are numerous and there is no longer a good relation between test weight and flour yield. In a personal communication, C. Greenwood of the British Flour Milling and Baking Research Association says test weight has little if any value in the United Kingdom, since it fails to correlate with other quality indexes including flour yield. He said test weight was used to some extent in 18th Century England as an index for detection of chaff or voluminous impurities such as stones. He sees little value in the test now or in the future in the United Kingdom.

Hall and Hill (6) state that in Europe few grain specialists consider test weight for corn of any value since it does not relate to other quality factors. They would like to see test weight for corn either proved of some value or removed from the standards.

Hlynka and Bushuk (7) state that the way kernels pack while filling a device and kernel density are factors which influence test weight. They demonstrated that kernel size does not influence test weight. Baker *et al.* (8) showed a highly significant correlation between test weight and flour yield.

Sander *et al.* (9) and McGinty and Watson (10) developed a physical test for wheat which may have more value than test weight. They determined kernel weight distribution by weighing individual kernels electronically on a computerized weighing system. They obtained precise information about kernel weight distribution in a sample which may provide valuable knowledge for millers and plant breeders.

In marketing grain, the metric system is being widely used throughout the world, and especially in European countries since the establishment of the

European Common Market. This requires the U.S. to report hectoliter weights on grain shipments. Therefore, appropriate tables for converting test weight to hectoliter weight based on experimental results were developed and are reported herein.

MATERIALS AND METHODS

A Hartner 1-liter hectoliter device (Fig. 1), purchased from Foss America, Rt. 82, Fishkill, NY 12524, was selected because it is one of the most widely used devices in Europe for determining hectoliter weight. Bushel weights were

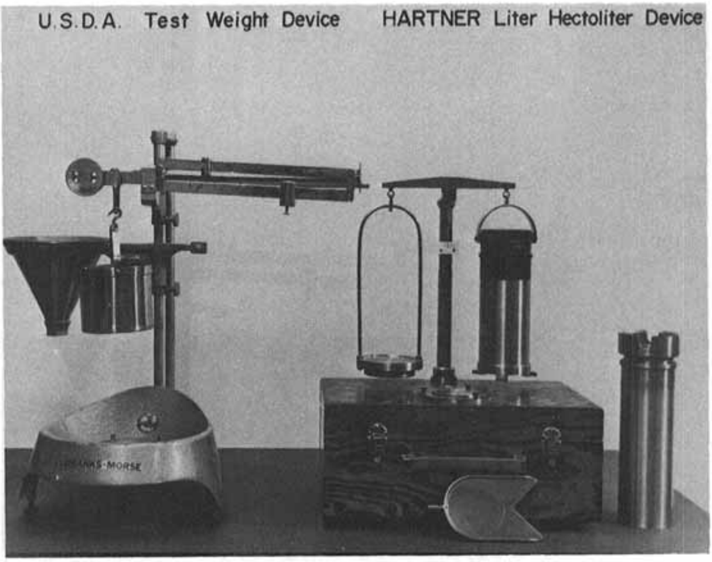

Fig. 1. Official USDA test weight device and Hartner 1-liter hectoliter device.

TABLE I
Means of Hectoliter and Bushel Weights Obtained on 50 Samples Each of Cereal and Other Crops by Two Operators, A and B

Crop	Hectoliter wt, kg				Bushel wt, lb			
	A		B		A		B	
Wheat	81.3	81.2	81.2	81.2	61.3	61.2	61.1	61.1
Corn	71.3	71.2	71.2	71.2	56.1	56.1	56.1	56.1
Oats	53.2	52.9	53.1	52.5	39.4	39.4	39.3	39.4
Barley	68.0	68.1	68.0	67.9	50.9	50.9	50.9	50.8
Grain Sorghum	68.7	68.3	68.9	68.4	52.9	52.7	52.8	52.9
Rye	76.6	76.6	76.4	76.4	57.1	57.0	56.9	57.0
Flax	67.1	67.1	66.9	66.9	50.0	50.0	50.0	49.9
Soybeans	70.6	70.6	70.5	70.6	56.1	56.0	56.0	55.9
Mean	69.6	69.5	69.5	69.4	53.0	52.9	52.9	52.9

determined with a standard USDA bushel weight device (Fig. 1) as described by the USDA (1).

Fifty 5-lb samples each of wheat, corn, barley, oats, grain sorghum, soybeans,

TABLE II

Test Values of Paired t-Test for Duplicates (D) and Operators (O) on Hectoliter and Bushel Weights for 50 Samples Each of Cereal and Other Crops

	Hectoliter wt		Bushel wt	
Crop	**D**	**O**	**D**	**O**
Wheat	0.99	2.66**	2.59*	6.52**
Corn	1.33	0.82	0.44	0.54
Oats	4.02**	5.15**	0.23	3.01**
Barley	1.00	1.75	0.28	2.89**
Grain sorghum	5.72**	6.09**	3.57**	5.59**
Rye	0.40	7.70**	3.81**	7.08**
Flax	0.31	5.65**	0.84	4.81**
Soybeans	1.97	2.64**	1.70	6.70**

TABLE III

Ranges, Correlation Coefficients, and Standard Errors of Estimate for Hectoliter and Bushel Weights within 50 Samples of Each Cereal and Other Crops

	Range			
Crop	**Hectoliter wt kg**	**Bushel wt lb**	**r**	**syx kg**
Wheat	75.6 – 85.6	56.7 – 64.4	0.986	0.40
Corn	61.0 – 73.6	48.0 – 58.2	0.992	0.28
Oats	35.0 – 59.9	27.6 – 44.5	0.995	0.44
Barley	63.6 – 72.1	48.1 – 53.3	0.989	0.35
Grain sorghum	52.8 – 75.6	39.9 – 58.0	0.996	0.64
Rye	73.2 – 79.4	54.6 – 59.1	0.990	0.23
Flax	64.2 – 69.2	48.0 – 51.3	0.982	0.22
Soybeans	67.1 – 73.0	52.4 – 58.1	0.988	0.23

TABLE IV

Correlation Coefficients and Standard Errors of Estimate for Hectoliter and Bushel Weights by Operator A *vs.* Operator B

	Hectoliter wt		Bushel wt	
Crop	**r**	**syx kg**	**r**	**syx lb**
Wheat	0.998	0.14	0.997	0.13
Corn	0.986	0.38	0.987	0.28
Oats	0.997	0.35	0.997	0.22
Barley	0.991	0.33	0.996	0.15
Grain sorghum	0.991	0.87	0.993	0.60
Rye	0.991	0.22	0.994	0.13
Flax	0.986	0.20	0.991	0.12
Soybeans	0.984	0.27	0.988	0.20

and flax with wide ranges in bushel weight were obtained from selected field offices of the Grain Division, Agricultural Marketing Service, USDA. Wheat, barley, and flax were tested after removal of dockage, whereas corn, oats, grain sorghum, and soybeans were tested on an "as-received" basis.

Two operators tested each sample of grain in duplicate on each of the two devices. Correlation coefficients and standard errors of estimate were determined, and a paired t-test was applied to the data.

RESULTS AND CONCLUSIONS

Averages for duplicate determinations for most grains differed by approximately 0.13 kg (0.02%) for hectoliter weight and 0.10 lb (0.16%) for bushel weight (Table I), acceptable degrees of error. Greatest hectoliter weight differences (0.45 kg, average of two operators) were for oats and grain sorghum; bushel weight differences between duplicates for both operators were minimal. Since both oats and grain sorghum were high in chaff content, the hectoliter weight device may be more sensitive to the presence of chaff than the bushel weight device.

The five statistically significant t-values under duplicates (Table II) are probably attributable to sampling error. The highly significant t-values under operators (13 of 16) suggest that the tests need to be further standardized.

Correlation coefficients for hectoliter *vs.* bushel weight are all high. The standard errors of estimate for grain sorghum and oats (Table III) indicate that further standardization of sampling and other techniques is desirable. Correlation coefficients and standard errors of estimate (Table IV) show good agreement between operators, except for grain sorghum (refer to t-values in Table II).

Based on our data, factors for converting bushel weight to hectoliter weight and vice versa are given in Table V. The theoretical factors for converting hectoliter weight to test weight and vice versa are 0.7768 and 1.2873, respectively. Comparing them to the theoretical factor demonstrates the extent to which the theoretical factor is altered by physical characteristics of the seed crops. Only

TABLE V
Factors for Converting Bushel Weight (BW) to Hectoliter Weight (HLW) and Vice Versa

Crop	Factor: BW to HLW	Factor: HLW to BW
Wheat	1.3264	0.7539
Corn	1.2695	0.7877
Oats	1.3446	0.7437
Barley	1.3365	0.7482
Grain sorghum	1.2952	0.7721
Rye	1.3426	0.7448
Flax	1.3412	0.7456
Soybeans	1.2594	0.7940
Theoretical	1.2873	0.7768

corn and soybeans have factors less than 1.2873. The conversion factor of 1.3264 for wheat agrees remarkably well with data obtained by the Department of Cereal Chemistry and Technology, North Dakota State University, Fargo, on commercial shipments of wheat to foreign ports and other unpublished data[6].

The hectoliter weight device we used requires many more manipulations than does the bushel weight instrument, thus doubling the time per test. Only one device was studied. Before official factors can be established, other devices and methodology should be evaluated.

[6]Personal communication with L. D. Sibbitt, Department of Cereal Chemistry and Technology, North Dakota State University, Fargo, ND 58102.

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